W. B. No. 766.

U. S. DEPARTMENT OF AGRICULTURE

U.S. WEATHER BUREAU

CHARLES F. MARVIN, Chief

MONTHLY WEATHER REVIEW

VOLUME 50, No. 2

FEBRUARY, 1922

WASHINGTON
GOVERNMENT PRINTING OFFICE
1922

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BACK NUMBERS OF THE REVIEW WANTED.

The Weather Bureau has not enough of the following numbers of the MONTHLY WEATHER REVIEW to meet even urgent requests for filling up files at institutions where the REVIEW is constantly being referred to. The return of any of these or of any 1919 or 1920 issues, especially November, 1919, will be greatly appreciated. An addressed franked slip may be had on application to the Chief, U. S. Weather Bureau, Washington, D. C.

1914: January, February, March, April, September, October, December.
1915: May, June, July, August.
1916: January, August.
1917: June.
1918: February, September.
1919: Any issue, especially November.
1920: Any issue, especially January.
SUPPLEMENT, No. 3.

PLATE 1.—Dense forest of western white pine, western red cedar, and western hemlock, in northern Idaho. The dense under story of hemlock and cedar burns readily and carries the flames into the crowns of the trees.

PLATE 2.—The forest devasted by fire.

MONTHLY WEATHER REVIEW

ALFRED J. HENRY, Editor.

Vol. 50. No. 2. W. B. No. 766. | FEBRUARY, 1922. | Closed April 3, 1922 Issued May 1, 1922

CLIMATE AND FOREST FIRES IN MONTANA AND NORTHERN IDAHO, 1909 TO 1919.

By J. A. Larsen, Forest Examiner, and C. C. Delavan, Fire Assistant.

[Priest River Forest Experiment Station, Idaho, 1920.]

INTRODUCTION.

The present report is a result of the study of the relation between climate and forest fires in Montana and northern Idaho. This region is designated as District I of the United States Forest Service. The data used are the weather records of the United States Weather Bureau for the regular and cooperative stations, and the detail fire reports of the United States Forest Service for the years 1909 to 1919, inclusive. Mr. C. C. Delavan has compiled the fire records and Mr. J. A. Larsen the weather data.

The splendid forests of western Montana and northern Idaho have, according to oral and visible records, always been subject to destructive fires. During the last 11 years the seriousness of the forest fire situation has been brought home by the fact that nearly 5,000,000 acres of land burned over in District I, with a total estimated damage to standing timber of over $28,000,000 and a total outlay in fire prevention and suppression of about four and one-half million dollars. This great destruction is gnawing at the vitals of the national timber supply.

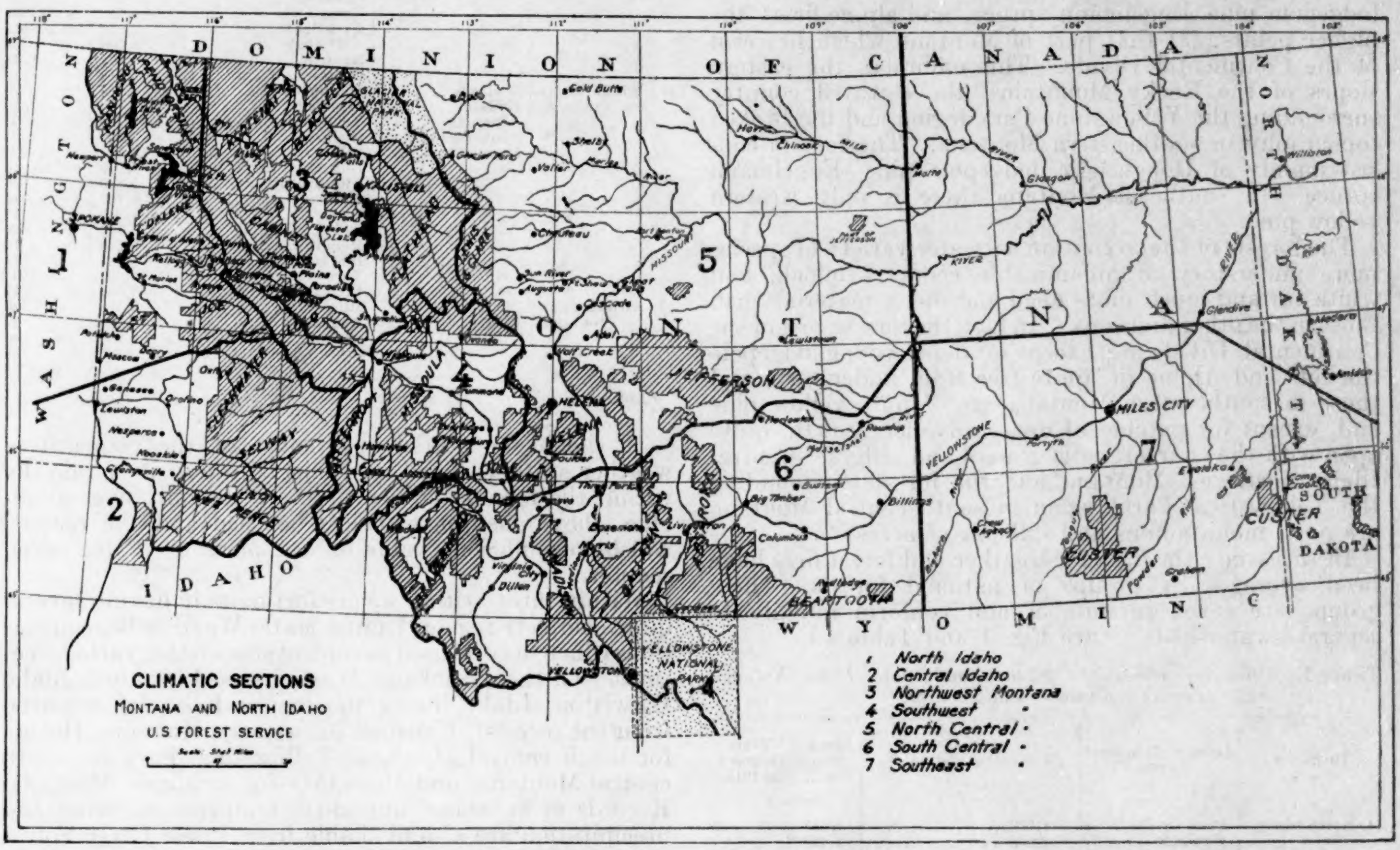

Fig 1.—Climatic sections of Montana and north Idaho.

By far the greater percentage of this damage has been visited upon Idaho and western Montana. This has been somewhat difficult to understand, especially since Idaho and western Montana show a greater annual precipitation than the sections farther east. The reasons underlying this should be understood so that methods of suppression and means of prevention may be guided by whatever information is obtainable.

It is the plan of this work to investigate the topographic and climatic causes for forest fires in the district generally and in Idaho in particular; to analyze the records of fires and climate for different years for a better understanding of the kind of season which results in bad forest fires; to study the records of fires and weather for individual months to see how much rainfall is needed to allay these fires; to set forth especially dangerous fire weather, the length and intensity of the fire season in the different sections under consideration; to examine the climatic

records for the last 40 years in order to discover whether or not the last three years are usual or unusual, and to discuss the chances of predicting very dangerous fire weather.

BROAD TOPOGRAPHIC CONTROLS OF CLIMATE AND FOREST DISTRIBUTION.

The region under discussion embraces three broad topographic divisions, as follows: (1) Idaho, north of the Salmon River, where the land rises gradually from 3,000 feet elevation of the Columbia River Plateau to the crests of the Bitterroot Divide, at from 6,000 to 7,000 feet elevation. The lower parts of the forest are composed mainly of western yellow pine and Douglas fir, the intermediate slope has western white pine, western larch, Douglas fir, western hemlock, western red cedar, and grand fir; (2) western Montana, which includes the land between the Bitterroot and the Continental Divides. In this part the elevations vary from 3,000 to 10,000 feet, and from prairies and forests of western yellow pine in the valley through forests of Douglas fir, western larch, lodgepole pine, Engelmann spruce, and alpine fir at the higher points; (3) that part of Montana which lies east of the Continental Divide. This embraces the eastern slopes of the Rocky Mountains, the elevated country surrounding the Yellowstone Park region and the broken topography in southeastern Montana. The forests consist mainly of Douglas fir, lodgepole pine, Engelmann spruce. In southeast Montana there is only western yellow pine.

The forests of Idaho contain a greater variety of species more understory of inflammable cedar, hemlock, and white fur and much more dead and down material than those in the other divisions. In fact, the forests east of the Continental Divide are, except for dense young lodgepole thickets and Alpine fir, quite free from understory, and those in southeastern Montana are of pure yellow pine and, except for patches of dense advance growth, quite open with the characteristic grasses and sedges. Central Idaho, northwest Montana, and the forests surrounding the Yellowstone Park region in south central Montana are most mountainous and difficult of access.

In this study the data for weather and forest fires have been averaged by groups of national forests. These groups are seven in number and conform roughly to separate watersheds. (See Fig. 1 and Table 1.)

TABLE 1.—*Climatic sections of Montana and north Idaho National Forests and weather stations used.*

Divisions.	Groups of national forests.	Weather station.	Elevation (feet).	Years recorded to 1918.
(1) North Idaho..	Pend Oreille......	Porthill..................	1,665	29
	Kaniksu..........	Bonners Ferry..............	2,429	8
	Coeur d'Alene.....	Sandpoint..................	2,100	8
	St. Joe............	Priest River...............	2,300	8 to 1906
		Priest River Experiment Station.	2,360	7
		Lakeview..................	2,250	18 to 1915
		Coeur d'Alene..............	2,157	24
		St. Maries................	2,155	19
		Murray....................	1,750	15 to 1908
		Kellogg...................	2,305	14
		Burke.....................	4,082	9
		Wallace...................	2,770	10
		Avery.....................	2,500	5
(2) Central Idaho.	Clearwater........	Moscow....................	2,748	26(1912-15)
	Selway............	Lewiston..................	757	25
	Nezperce..........	Deary.....................	2,854	4
		Orofino...................	1,027	14
		French Gulch..............	4,000	5
		Kooskia...................	1,261	10
		Musselshell...............	3,171	5
		Nezperce..................	3,082	9
		Oxford....................	3,735	4
		Potlatch..................	2,550	3
		St. Michaels Priory.......	4,000	6
		Elk City..................	5,756	5

TABLE 1.—*Climatic sections of Montana and north Idaho National Forests and weather sections used*—Continued.

Divisions.	Groups of national forests.	Weather stations.	Elevation (feet.)	Years recorded to 1918.
(3) Northwest Montana.	Kootenai..........	Kalispell..................	2,965	20
	Blackfeet.........	Columbia Falls.............	3,100	22
	Cabinet...........	Fortine....................	2,975	12
	Lolo..............	Dayton.....................	2,925	13
	Flathead..........	Plains.....................	2,473	19
		Thompson Falls.............	2,424	6
		Libby......................	2,075	22
		Troy.......................	1,880	16 to 1910
		Haugan and St. Regis.......	3,150	9
(4) Southwest Montana.	Bitterroot.........	Missoula...................	3,225	38
	Missoula..........	Hamilton...................	3,525	....
	Deerlodge.........	Como.......................	3,750	10
		Ovando.....................	4,050	20
		Hat Creek..................	....	....
		Phillipsburg...............	5,273	14
		Anaconda...................	5,330	18
		Butte......................	5,716	23
		Deerlodge..................	4,509	15
(5) North central Montana.	Helena............	Babb.......................	4,461	12
	Lewis and Clark..	Helena.....................	4,110	38
	Jefferson.........	Adel.......................	5,200	19
		Wolf Creek.................	3,460	14
		Cascade....................	3,361	13
		Great Falls................	3,350	26
		Fort Benton................	2,630	33 to 1912
		Fort Shaw..................	3,500	23
		Augusta....................	4,071	18
		Choteau....................	3,810	19
(6) South central Montana.	Madison...........	Harlowton..................	4,160	23
	Gallatin..........	Bozeman....................	4,900	20
	Absaroka..........	Yellowstone................	6,200	33
	Beaverhead........	Redlodge...................	5,548	17 (18)
	Beartooth.........	Billings...................	3,115	21 (22)
		Busted.....................	4,050	10
		Virginia City..............	5,880	29
		Hebgen Dam.................	6,700	12
		Norris.....................	4,845	11
		Dillon.....................	5,143	20
		Renova.....................	4,360	19
		Bowen......................	6,080	11
		Three Forks................	4,400	12 to 1915
		Big Timber.................	4,094	12
(7) Southeast Montana.	Sioux.............	Miles City.................	2,378	26
	Custer............	Ekalaka....................	[1] 4,000	17
		Graham.....................	[1] 4,000	10
		Crow Agency................	3,401	38

[1] About.

It should be stated that most of the cooperative weather stations listed in Table 1 do not, as a rule, lie within the forests. Since they are the only ones available, they must nevertheless be used and the records will be of sufficient value for comparisons of the seven sections.

Within this territory we are fortunate in having several quite complete regular United States Weather Bureau stations which may be used as control stations for various sections. Of these Spokane, Wash., is used for north Idaho (Lewiston, Idaho, being too low and too far removed from the forests), Kalispell for western Montana, Helena for north central Montana, Yellowstone Park for south central Montana, and Miles City for southeast Montana. Records of sunshine, humidity, temperature, wind and precipitation are also available from Priest River Forest Experiment Station, within the timbered belt of northern Idaho.

In presenting the data on climate for use in this study, the year is begun October 1, for in this manner it is possible to review at a glance all of the factors which may or may not contribute toward a bad fire season.

FIRES AND CLIMATE BY THE SEVEN SECTIONS.

The data on forest fires, 1909 to 1919 by area, damage, cost, causes and classes are given in Tables 2 and 3 and are shown graphically in Figures 2, 3, 4, 5, and 6. The weather records for the same years are presented in Tables 4, 5, and 6.

TABLE 2.—*Fires according to the seven sections, 1909–1919, inclusive.*

Section.	Total national forest area.	Area burned per each 100,000 acres.	Average area per fire.	Estimated damage per fire.[1]
	Acres.	*Acres.*	*Acres.*	
North Idaho	3,476,380	22,728	234	$2,954
Central Idaho	4,375,925	45,750	1,154	4,256
Northwest Montana	6,986,718	19,332	281	1,940
Southwest Montana	3,488,059	6,121	130	471
North central Montana	2,922,525	8,003	410	1,433
South central Montana	4,979,930	924	97	497
Southeast Montana	710,619	1,077	48	277
Total	26,940,156			
Average		17,237	363	2,236

[1] The damage is the estimated value of timber and young forest destroyed.

TABLE 3.—*Numbers of fires in the seven sections, by classes and causes, 1909–1919, inclusive.*

Section.	Total number.	Number per 100,000 acres.								
		A.	B.	C.	Railroads.	Lightning.	Brush burning.	Campers.	Unclassified.	Total.
North Idaho	3,381	59.3	20.9	17.1	32.2	23.0	10.8	10.0	21.3	97.3
Central Idaho	1,735	19.4	9.9	10.4	.0	33.1	7.3	2.0	3.7	39.6
Northwest Montana	4,813	38.2	17.6	13.1	31.3	13.8	7.5	5.6	10.7	68.9
Southwest Montana	1,648	24.4	12.9	9.9	9.8	13.0	4.0	11.7	8.8	47.2
North central Montana	571	10.6	4.7	4.3	8.0	5.2	1.4	1.8	3.1	19.5
South central Montana	473	5.2	2.1	2.3	1.2	2.0	.7	2.7	2.9	9.5
Southeast Montana	160	7.0	8.0	7.5	.0	10.8	.1	3.7	7.9	22.5
Total	12,783									
Average	1,826	26.1	11.6	9.7	14.7	14.8	4.2	5.4	8.3	47.4

The data presented in Tables 2 and 3 show an average of close to 17,250 acres burned per each 100,000 for the entire district from 1909 to 1919. North and central Idaho and northwest Montana suffered most. These three sections have about 89 per cent of the total area which was burned; northwest Montana 19 per cent, north Idaho 17 per cent, and central Idaho 43 per cent. This great difference between the western and eastern sections appears to be due both to the relative number of fires and the areas per fire in each section. (See Table 3 and fig. 3.) Montana, east of the Continental Divide, shows an average number from 9.5 to 22.5 of fires per 100,000 acres, while the western parts show 39.6 to 97.3. The eastern sections show an average area per fire from 48 to 410 acres; north Montana and north Idaho 281 and 234, respectively, and central Idaho 1,154 acres per fire. In the last instance the high acreage is due chiefly to large fires in 1910 and 1919.

The damage per fire, given in Table 2, is based on estimates of merchantable-sized timber (stumpage) destroyed and of additional values of reproduction and young growth. If watershed values, grazing, and other phases were included, the figures would be much greater. They are mentioned here mainly for the purpose of bringing out the relations between the sections in this respect. Damage figures for southeast Montana are the lowest, as is also the average area per fire.

Fires which cover more than 10 acres are classed as C fires, and those which burn less than ¼ acre as A fires. Those between ¼ and 10 acres are B fires. Large fires are most numerous in the west and relatively few in the east, except in southeast Montana, where there are many surface fires.

In respect to the number of fires southwest Montana may be classed with the western sections, but from a standpoint of area per fire it resembles the eastern parts.

The outstanding causes of forest fires in this district are lightning, railroads, campers, and slash burning, of which lightning is the cause of the greatest number. By individual sections it appears that railroads are the most prolific source in north Idaho, northwest Montana, and north central Montana. Central Idaho and southeast Montana are free from railroads and railroad-caused fires. Central Idaho has comparatively few fires from any

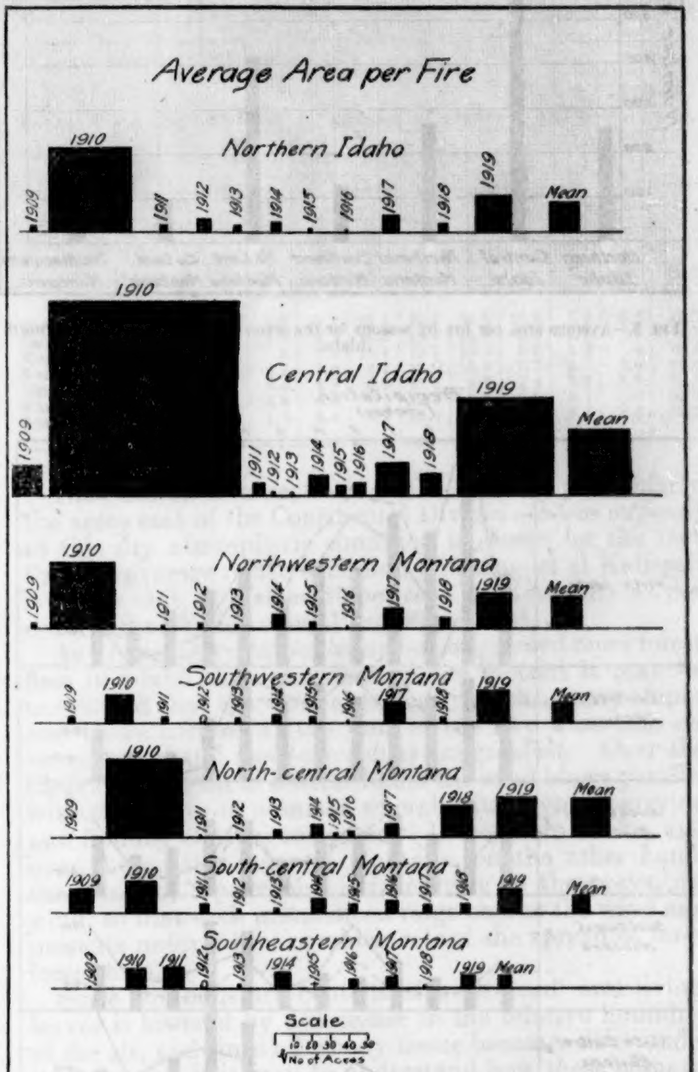

FIG. 2.—Average area per fire for the seven sections of Montana and north Idaho.

cause except lightning, which causes 84 per cent of all fires. Slash burning is the cause of many fires getting beyond control in north Idaho and northwest Montana. Many of the fires listed under this cause have, no doubt, been set in slash by parties who desire either to clear land or to comply with the State law compelling burning of slash.

The essential climatic elements, such as sunshine, air temperature, relative humidity, wind, and precipitation, including snowfall, are given in Tables 4, 5, and 6. In looking over these figures there does not appear to be any remarkable difference in the air movement, somewhat

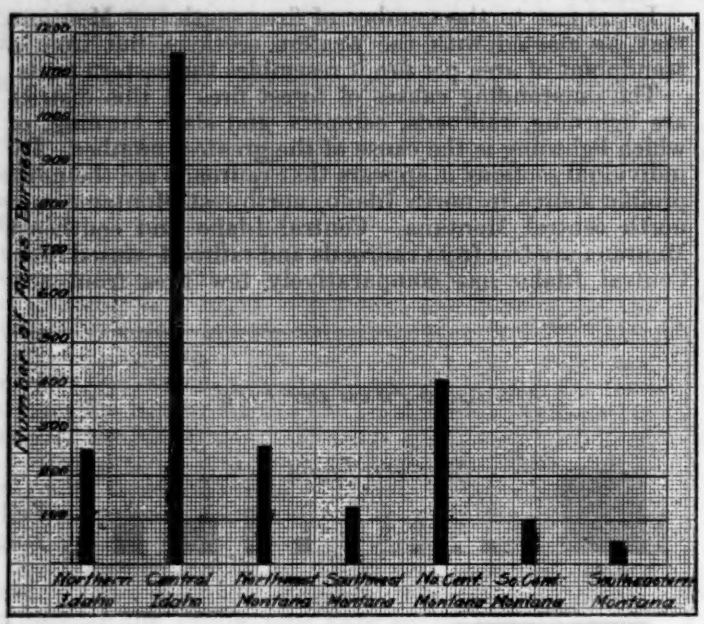

FIG. 3.—Average area per fire by seasons for the seven sections of Montana and north Idaho.

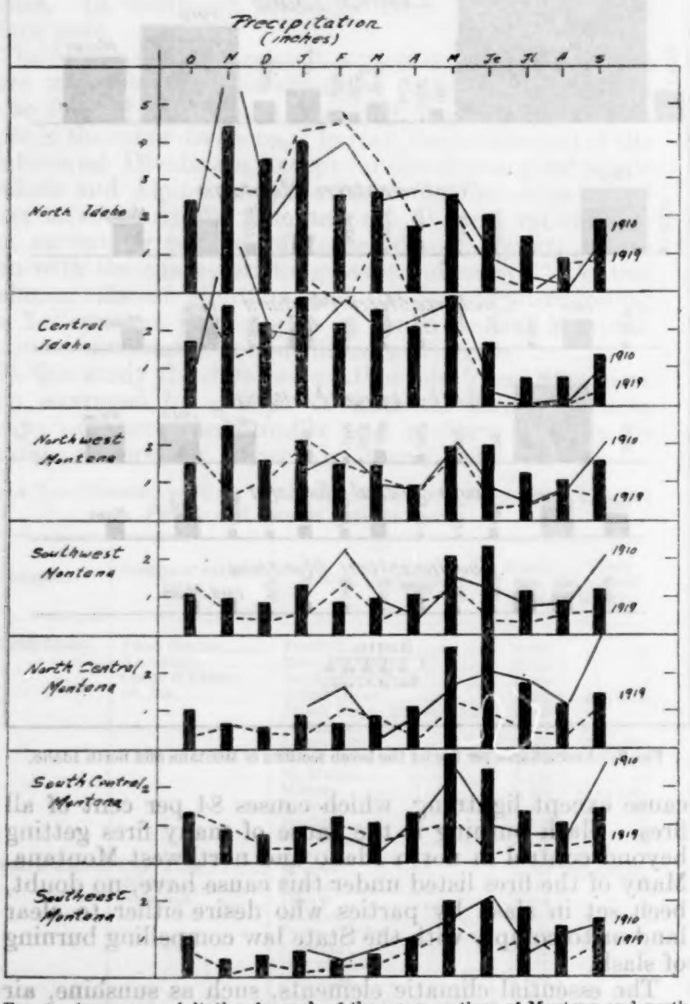

FIG. 4.—Average precipitation for each of the seven sections of Montana and north Idaho. (Based on published data of U. S. Weather Bureau for stations listed in Table 1.)

greater, to be sure, at Helena and Yellowstone Park. The average annual air temperatures do not differ so very much, but eastern Montana has a much colder winter and southeastern Montana a warmer summer than the western sections. Of the latter, central Idaho shows the warmer summer.

Precipitation, however, differs in a very striking manner; north Idaho has an annual average of 30.37 inches and eastern Montana only 14.22 inches. Central Idaho has only 1.40 inches for July and August, and eastern Montana nearly 3 inches. Central and western Montana sections are again intermediate. These differences are due to the fact that Idaho partakes of the Pacific coast type of precipitation and eastern Montana the continental type.

The greater amount of sunshine at Spokane in summer than at the other control stations, and the lower relative

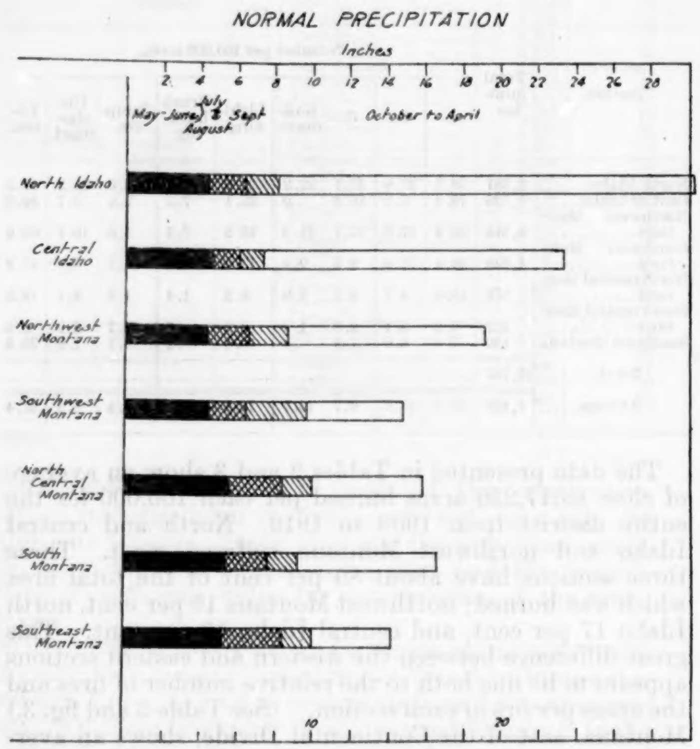

FIG. 5.—Precipitation by months for the seven climatic sections of Montana and north Idaho.

humidity reflect the dry summers west of the Bitterroot Range. The light snowfall in central and eastern Montana illustrates the lighter winter precipitation in these parts.

In Idaho this low rainfall in summer, which is accompanied by much sunny, warm weather and low humidity, produces a critical forest fire situation almost every year.

The reason for the greater devastation of forest by fire in Idaho would seem to be in the fact that, particularly in central Idaho, the summer rainfall and relative humidity are so much less than in the other sections. The heavier annual precipitation in Idaho, which is also usually abundant in spring, gives rise to a dense forest, often with a mass of undergrowth and much dead and down material, which by virtue of the low summer rainfall and low humidity become highly inflammable. The primary cause of this dry condition is found in the pre-

vailing westerly winds, which lose moisture in passing the Cascades, become heated by compression in the descent on the eastern slopes, and create desert conditions over a stretch of 100 miles of flat land, where they are further heated without receiving any additional moisture. When these winds strike the forests, therefore, they exert a powerful drying influence.

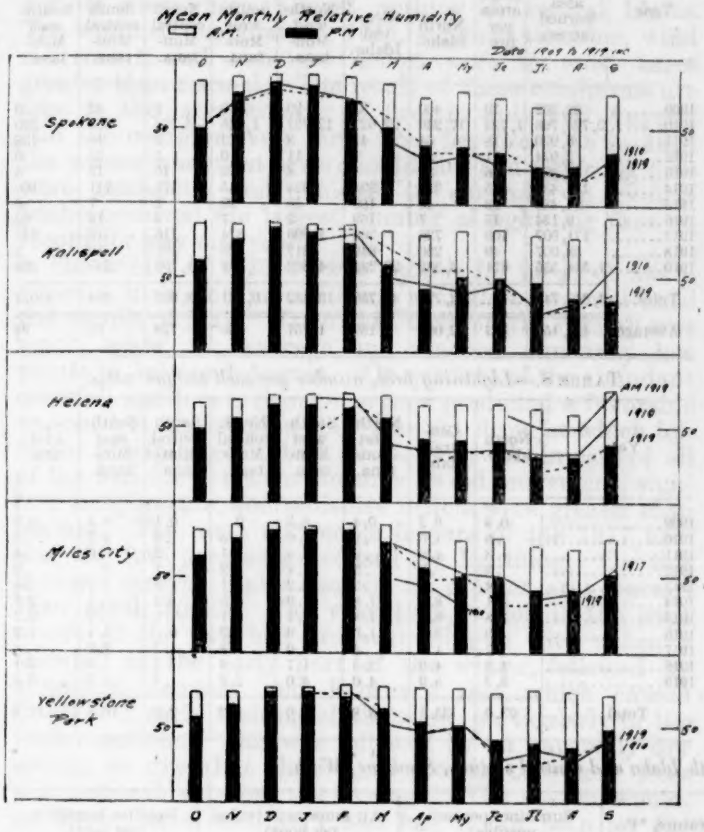

FIG. 6.—Relative humidity by months for the seven sections of Montana and north Idaho.

TABLE 4.—*Average precipitation.*

[Data from stations listed Table 1, U. S. Weather Bureau.]

	October.	November.	December.	January.	February.	March.	April.	May.	June.	July	August.	September.	Year.
North Idaho	2.43	4.43	3.55	3.90	2.60	2.65	1.78	2.60	2.07	1.50	0.92	1.94	30.37
Central Idaho	1.82	2.55	2.10	2.56	2.10	1.97	1.95	2.24	1.56	.70	.70	1.26	21.51
Northwest Montana	1.48	2.50	1.60	2.10	1.47	1.46	.90	1.93	2.00	1.25	1.07	1.54	19.30
Southwest Montana	1.07	.97	.82	1.30	.86	.96	1.05	2.08	2.32	1.15	.90	1.28	14.76
North central Montana	1.05	.68	.59	.86	.65	.86	1.09	2.67	3.00	1.72	1.20	1.48	15.85
South central Montana	1.30	.86	.75	.91	1.20	1.04	1.30	2.85	2.46	1.37	1.06	1.45	16.55
Southeastern Montana	.98	.47	.52	.61	.50	.72	1.11	2.41	2.63	1.50	1.30	1.47	14.22

AVERAGE AIR TEMPERATURE (F.°).

North Idaho	45.5	35.4	28.4	26.0	28.5	36.7	45.0	51.3	56.0	65.5	63.8	54.5	44.7
Central Idaho	48.6	39.3	30.9	27.9	31.6	40.6	48.2	53.8	61.9	67.8	66.0	56.4	47.7
Northwestern Montana	44.5	34.3	26.0	22.5	26.4	35.2	45.0	53.0	58.4	64.3	63.0	52.5	42.8
Southwestern Montana	43.5	33.5	24.6	22.0	23.2	33.0	42.5	49.0	57.0	63.5	62.0	53.2	42.2
North central Montana	44.6	30.5	24.3	20.5	22.6	25.8	41.5	50.8	58.8	64.8	64.0	55.2	41.8
South central Montana	44.5	32.0	24.5	19.8	22.5	30.5	41.2	50.3	59.3	65.9	63.2	55.0	42.4
Southeastern Montana	46.1	31.5	21.9	16.5	18.9	30.1	43.5	54.1	63.7	70.4	68.9	59.5	44.7

TABLE 5.—*Humidity, sunshine and wind.*

Control station.	Relative humidity (per cent).					Sunshine per cent of possible.			Wind movement (miles per hour).	
	Average for summer.[1]		Lowest monthly in summer.		Average, August, P. m.	Summer.[1]	Average, August.	Maximum monthly.	Summer.[1]	Average, August.
	P. m.	A. m.	P. m.	A. m.						
Spokane	32.5	70	16	51	25	65	74	89	6.2	5.3
Kalispell	44.7	82	27	......	36	60.5	69	87	4.8	4.4
Helena	37.6	63	22	40	30	65	73	88	7.1	7.8
Yellowstone Park	44.7	75	26	63	36	62.6	72.6	....	7.4	6.9
Miles City	49.0	75	28	......	42	....	....	....	6.0	5.1

[1] April to September, inclusive.

TABLE 6.—*Average snowfall for sections of Montana and north Idaho.*

[Data 1909-1919, inclusive, in inches.]

Section.	October.	November.	December.	January.	February.	March.	April.	May.	Total.
North Idaho	0.5	9.1	19.4	21.3	19.8	10.8	1.2	0.2	82.3
Central Idaho	1.0	5.2	11.5	18.9	16.7	8.5	2.0	.9	64.7
Northwest Montana	.8	7.9	15.4	19.7	15.5	8.5	1.2	.4	79.4
Southwest Montana	4.7	7.0	9.1	15.2	13.8	7.7	3.9	2.6	64.0
North central Montana	8.0	4.8	5.9	10.3	9.0	7.4	5.3	3.0	53.7
South central Montana	5.8	6.8	7.9	12.0	9.6	8.8	6.1	5.9	62.9
Southeastern Montana	1.8	4.6	6.9	10.3	4.8	6.6	3.4	2.3	39.7

That the eastern sections of the district, particularly the areas east of the Continental Divide, are less exposed to this dry atmospheric condition is shown by the fact that the average relative humidity for August at Kalispell is 36 per cent, at Helena 30 per cent, at Miles City 42 per cent, and at Yellowstone Park 36 per cent.

As to secondary causes contributing toward more forest fires in Idaho than elsewhere in the district it may be mentioned that the wind always strikes the sunny slopes and blows hardest at the time of the day when the air temperature and moisture deficit are greatest. Over the Clearwater region in central Idaho the wind blows parallel with the ridges in summer whereby its drying, carrying and fanning effect is increased. In northern Idaho, and over the greater parts of Montana, on the other hand, the trend of topography is transverse to the prevailing wind, so that each pronounced ridge checks the wind and presents natural breaks which retard the spread of large forest fires.

Since the moisture content of both dead[1] and living[2] leaves is lowered by a decrease in the relative humidity of the air, and since all woody tissue becomes drier under its influence, it is easy to understand how these climatic and topographic relations produce the critical conditions which result in the bad forest fires in Idaho.

[1] By the investigations of S. B. Show, Climate and Forest Fires in California, Journal of Forestry, December 1919, p. 915, and by the Priest River Experiment Station it has been found that the dead material on the forest floor receives and gives up moisture according to the relative amount of moisture in the atmosphere.

[2] "In the case of specialized water tissue, the water which forms in the bulk of the cell represents a store which is drawn upon by other living tissue and in particular by the photosynthetic cells, in time of drought."—(*Plant Anatomy*, by Haberlandt.)

FIRES AND CLIMATE ACCORDING TO YEARS.

The data on fires by years are given in Table 7 and the weather conditions (for north Idaho and north-central Montana) appear in Tables 9 and 10.

A compilation of fires which are caused by lightning is given in Table 8. These data may be taken as fair indications of the hazard from this cause. It is of interest to note that 56 per cent of the total number is confined to the two Idaho sections. Lightning activity is greatest in Idaho, intermediate in western Montana and relatively small in the central Montana sections but somewhat increased again in southeastern Montana.

The fire records for the entire district for the last 11 years show six years comparatively free from bad forest fires. These are 1911, 1912, 1913, 1915, and 1916. These years show one and sometimes two of the summer months with deficient rainfall, but the summer averages were above normal. The beginning of 1915 occasioned considerable anxiety by an unusually early and warm spring, but the late spring and summer rains were abundant.

In marked contrast to these favorable seasons are the five years of bad forest fires, 1910, 1914, 1917, 1918, and 1919.

The year 1910 will always be remembered as one of the very worst fire years in the Pacific Northwest. More timber land was burned over in that year than during all of the 10 years following. The damage was particularly heavy in northern Idaho.

In going over the weather records for this year it is seen that the snowfall and the winter precipitation were about average. Even the month of May showed a fair amount of rain, but from the beginning of June until the latter part of August the drought was intense. During this summer Spokane and all the other Weather Bureau control stations in the district showed air temperature, wind movement, and moisture deficit greater than normal. The fire season came to a close with snow about August 19.

TABLE 7.—*Fires according to years.*

Year.	Total area burned (acres).	Average areas per fire.	Number of acres burned per each 100,000 acres.						
			North Idaho.	Central Idaho.	Northwest Montana.	Southwest Montana.	North central Montana.	South central Montana.	Southeast Montana.
1909	22,392	19	400	85	29	19	0	42	0
1910	2,725,796	1,724	17,246	22,627	12,731	1,646	5,755	368	390
1911	6,920	18	64	45	3	23	1	10	158
1912	2,974	11	59	1	11	0	1	11	0
1913	3,090	6	34	4	8	22	10	12	8
1914	114,433	55	321	993	624	145	171	111	100
1915	14,480	13	49	186	50	22	2	7	0
1916	9,134	15	7	159	2	7	9	18	62
1917	171,907	106	726	766	1,096	874	116	19	248
1918	58,067	49	260	649	217	25	137	12	1
1919	1,514,555	671	3,562	20,235	4,562	3,338	1,799	335	109
Total	4,643,748	......	22,728	45,750	19,332	6,121	8,003	924	1,077
Average.	422,159	363	2,066	4,159	1,757	556	728	84	98

TABLE 8.—*Lightning fires, number per each 100,000 acres.*

Year.	North Idaho.	Central Idaho.	Northwest Montana.	Southwest Montana.	North central Montana.	South central Montana.	Southeast Montana.	Average.
1909	0.9	0.2	0.4	0.3	0	0.1	0.3	0.3
1910	.8	1.6	.8	.6	.5	.3	2.7	.8
1911	.3	1.0	.3	.4	.1	.2	.6	.4
1912	.3	.3	.3	.1	.2	.1	0	.2
1913	.4	.9	.3	.2	.1	0	1.1	.3
1914	3.1	8.7	1.8	1.9	.5	.3	.7	2.7
1915	7.8	6.2	1.8	1.1	.1	.1	.1	2.7
1916	.9	3.2	1.0	1.6	.2	0	1.4	1.2
1917	.7	1.2	.8	1.0	.8	.3	2.2	.8
1918	4.5	4.0	2.3	1.7	.4	.2	.4	2.1
1919	3.3	5.9	4.0	4.0	2.2	.5	1.3	3.3
Total	23.0	33.1	13.8	13.0	5.2	2.0	10.8	14.8

TABLE 9.—*Weather conditions by years for north Idaho and control station, Spokane, Wash.*

Year.	Precipitation (inches).									Air temperature, °F.				Sunshine (per cent possible).				Air movement (miles per hour).				Relative humidity (per cent).			
	Snowfall.	October-December, inclusive.	January-March, inclusive.	April.	May.	June.	July.	August.	September.	May.	June.	July.	August.	May.	June.	July.	August.	May.	June.	July.	August.	May.	June.	July.	August.
1910	102	11.68	10.14	2.72	2.55	0.81	0.26	0.18	1.56	54.5	57.5	65.8	60.2	73	75	88	74	7.0	7.4	6.4	5.7	31	29	19	22
1912	89	7.02	6.89	1.96	2.92	2.10	1.70	2.38	1.46	53.2	62.0	62.0	60.0	64	68	66	60	6.4	6.0	5.6	5.9	40	34	34	39
1914	70	7.39	9.52	1.22	1.77	2.20	1.24	.32	2.48	54.5	57.5	67.0	64.5	62	53	82	79	6.1	6.9	5.8	5.7	34	33	22	19
1916	143	10.60	13.20	1.91	2.37	3.23	2.08	1.24	2.33	46.8	55.6	61.2	62.0	43	58	73	81	8.1	6.1	7.1	5.0	41	38	30	25
1917	137	8.05	8.77	2.98	2.05	1.30	.04	.08	.83	51.3	56.6	66.0	64.6	51	75	86	90	6.2	7.8	6.8	5.3	40	31	18	17
1918	80	12.55	11.15	.75	.16	.70	1.25	.25	.12	49.5	63.5	67.0	61.2	[1]55	78	74	70	8.4	6.2	5.6	6.0	33	22	25	34
1919	69	8.95	12.36	1.97	1.98	.42	.08	.78	.88	52.7	59.3	67.2	65.2	[2]72	88	89	81	8.3	6.6	5.9	5.6	35	33	21	16
Average for complete record [3]	82	10.41	9.12	1.78	2.60	2.07	1.50	.92	1.94	51.9	58.8	64.6	63.2	58	68	77	[1]76	6.8	6.9	5.9	5.2	38.2	33.2	25.3	25

[1] 73 in April. [2] 78 in April. [3] 1880-1910.

TABLE 10.—*Weather conditions by years and months for north central Montana and for the Helena, the control, station.*

Year.	Precipitation (inches).									Air temperature, °F.				Sunshine (per cent possible).				Wind movement (miles per hour).				Relative humidity (per cent).			
	Snowfall.	October-December, inclusive.	January-March, inclusive.	April.	May.	June.	July.	August.	September.	May.	June.	July.	August.	May.	June.	July.	August.	May.	June.	July.	August.	May.	June.	July.	August.
1910	45	......	2.74	0.89	1.73	2.01	1.80	1.17	3.33	53.7	60.8	67.3	61.1	57	57	72	80	7.7	6.9	6.8	6.3	34	36	32	32
1912	50	3.31	1.98	1.02	3.75	.88	2.00	2.28	2.35	51.3	60.6	60.9	61.0	57	55	77	62	9.4	8.6	8.0	8.2	52	43	46	42
1914	55	3.88	1.59	1.36	2.79	5.17	.41	.33	.75	52.7	57.7	69.0	63.5	56	57	71	69	8.3	8.8	8.3	8.5	45	49	33	30
1916	52	2.32	3.07	1.39	4.10	5.55	2.15	1.32	1.87	47.0	56.5	65.5	63.0	44	60	68	81	9.9	9.2	8.6	8.1	48	47	38	47
1917	85	3.87	3.22	1.70	3.74	1.62	.35	1.18	2.27	48.8	56.6	68.3	64.0	55	75	88	78	8.2	9.1	8.7	7.9	50	37	24	32
1918	51	3.10	2.25	1.38	1.36	1.07	2.25	1.50	1.87	48.3	64.4	64.7	62.4	53	77	64	66	9.2	8.2	7.2	8.5	36	31	38	36
1919	34	1.35	2.09	.21	1.24	.89	.43	.38	1.30	53.7	62.4	68.8	66.9	[1]61	61	71	80	9.2	8.3	8.7	8.1	[2]34	34	33	22
Average for complete record	54	2.32	2.59	1.09	2.61	3.00	1.72	1.20	1.48	50.7	59.6	65.1	63.3	[3]60	[3]65	[3]73	73	[4]6.8	[4]7.2	[4]7.7	7.8	42	41	31	30

[1] 62 in April. [2] April 28 per cent. [3] Years 1909-1919. [4] 19 years, 1916.

The season of 1914 was preceded by a normal fall, winter, and spring precipitation, but there was a marked deficiency of snowfall and an early melting. The May and June rainfall was about average, but somewhat low in May and high in June. The drop in July was most pronounced in the northwestern and the central Montana sections; the August rainfall was considerably below normal everywhere, almost nothing in central Idaho. The summer temperature, 1914, summer sunshine, wind movement, and moisture deficit were in most cases greater than normal. The result of these conditions are seen in the large number of fires in July and August, and the comparatively large area per fire. As in 1918 the season was most severe in Idaho, and lightning fires were numerous and difficult to control. In central Idaho occurred the largest number of lightning fires on record for any one year.

The winter of 1916–17 was notable for its great quantities of snow and precipitation well above normal until the month of May. From that time on the rainfall was much below the average and reached unusually low points in July and August. On account of the abundant snowfall and late melting everyone predicted a favorable season, but the sudden and unusual drought which followed precipitated a bad fire season. As in case of all of the bad fire years the sunshine, wind movement, summer temperature, and moisture deficit were greater than normal. The most noticeable feature of the 1917 fires was the low percentage caused by lightning. On this account central Idaho showed no greater area burned than north Idaho. The year 1918, which is the least severe of the five bad fire years, began with a heavy snowfall in the early part of the winter, followed by abundant January and February rain, which caused floods and early melting of the snow, particularly in the Idaho sections. This was followed by an unusually dry spring; so dry that the height growth of young trees was noticeably below the average. The season would, no doubt, have been very bad had it not been for the abundant rains in the middle of July. In all except the central Montana sections the May and June temperature, sunshine, wind movement, and moisture deficit were greater than normal. The fire season, based on number and area of fires, was much more severe in the Idaho than in the Montana sections and began exceptionally early. The number of lightning fires was in most sections well above the average.

The year 1919 had an unusually large number of fires in all parts of the district. It had the dryest spring and summer on record since 1883 on the Pacific slope and the dryest on record for the eastern slope (observation begun 1880, see fig. 12 and Table XII). The deficit in total annual precipitation from October 1, 1918, to September 30, 1919, is as follows: North Idaho 5 per cent, northwest Montana 27 per cent, southwest Montana 42 per cent, north central Montana 46 per cent, and in southeast Montana 51 per cent, with corresponding deductions elsewhere. The deficit for May, June, July, and August combined in each section are, in the order usually given: 42 per cent, 50 per cent, 50 per cent, 63 per cent, 66 per cent, 72 per cent, 54 per cent. Central Montana shows the greatest summer deficit. The more outstanding facts for the whole district for 1919 are: A very light snowfall everywhere; frozen ground in the fall; much melting of snow in late December, 1918; most of winter precipitation in the form of rain; comparatively little spring rain, followed by an unusually dry and a very warm summer; it was, moreover, the third consecutive dry season. Sunshine, wind movement, and mositure deficit were much above the average for all sections. It should be noted that the average afternoon July and August relative humidity for Spokane was only 18.5 per cent as compared with a normal of 25.2 per cent. The deficit at Helena for the same period was 9 per cent; for Yellowstone Park, 18 per cent; and for Miles City, 8.5 per cent. The average sunshine at Spokane for July and August, 1919, was 80 per cent and 85 per cent, compared with averages of 62.5 per cent and 70.5 per cent. It was also well above the average at

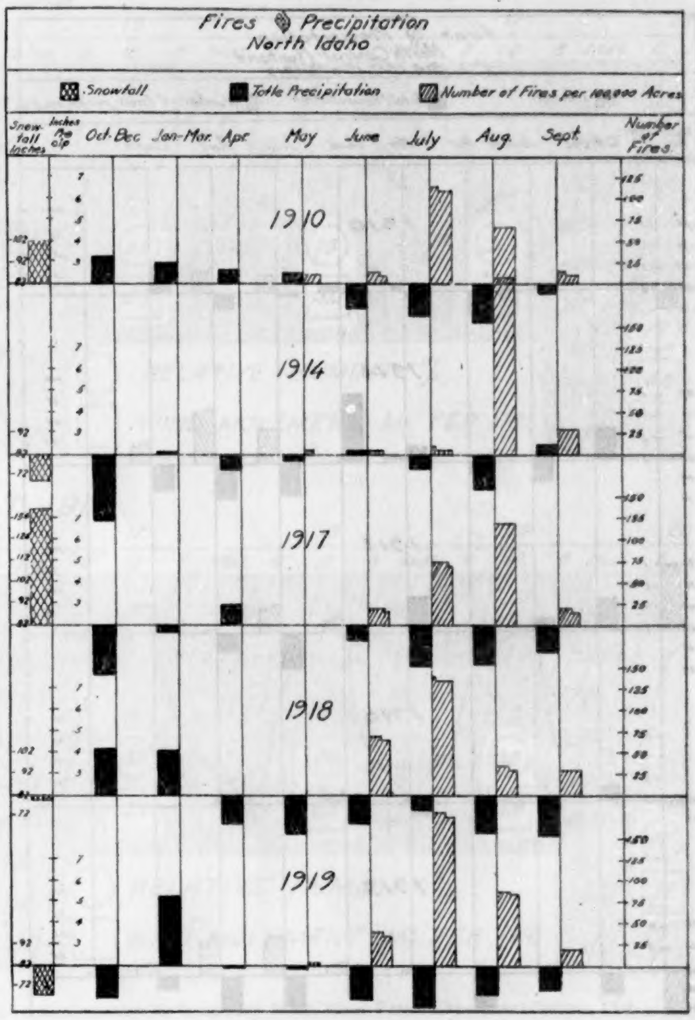

FIG. 7.—Deficit in rainfall and forest fires for north Idaho, 1910, 1914, 1917, 1918, and 1919.

the other control stations. Air movement at Spokane, Kalispell, and Yellowstone Park were considerably above normal and greater than in any previous fire year.

The light snowfall, lack of spring rain, and spring temperatures above normal were the causes of the unusually early start of the fires in 1919. The May fires in nearly every group exceeded both the 11-year average and those of any other single year. Fires in June were numerous in all parts of the district, and, while they did not burn with the same fierceness that the fires did later in the season, considerable difficulty was experienced in controlling them, principally, because of the fact that the protective force was just being put on.

FIRES AND WEATHER BY MONTHS.

A comparison of fires and weather by individual months brings out many points worth noting; but since the presentation of the data in tabular form leads to such a great mass of detail a diagrammatic presentation is given. This requires less space and can be more readily visualized.

The correlation which is given in figures 7 and 8 was carried out for all of the seven groups in the district. Only two of these are given here and one which shows the average relations for 1910, 1914, 1917, 1918, and 1919 for four sections.

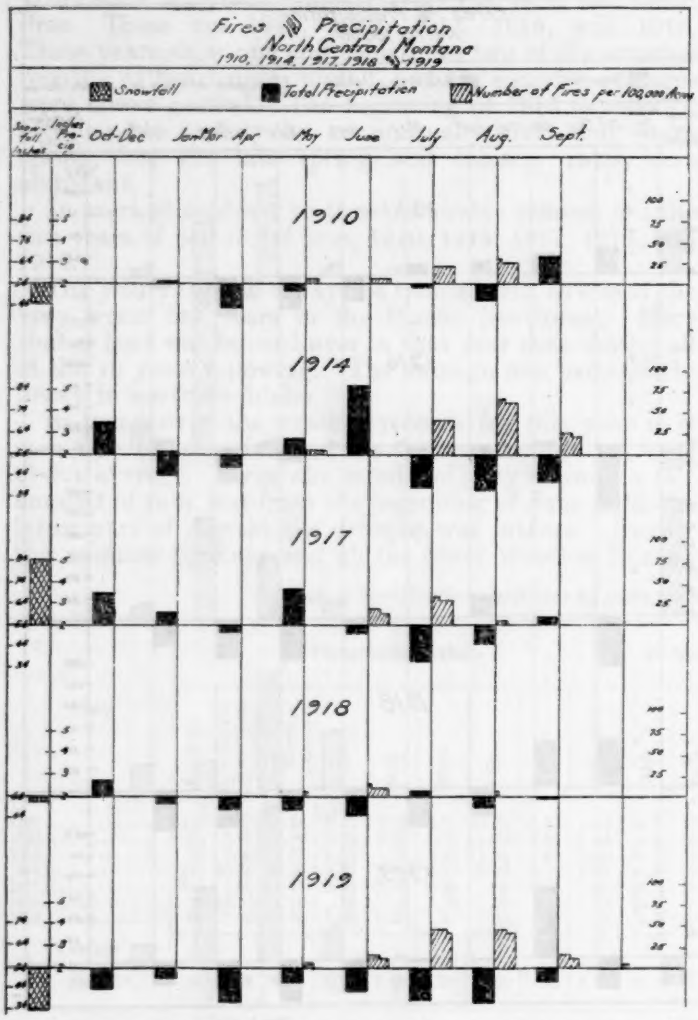

FIG. 8.—Comparison of precipitation and forest fires for north-central Montana, 1910, 1914, 1917, 1918, and 1919.

In these diagrams the difference between 2 inches of rainfall and the actual amount which fell has been used, mainly because the rainfall data for the safe years 1911, 1912, 1913, 1915, and 1916 show that 2 inches per month comes close to the safety limit in July and August.

It is recognized, however, that it is difficult to establish these relations definitely, mainly, because the origin of the fires, and especially lightning fires, vary widely from year to year. However, by averaging the number of fires and the precipitation for each month these relations may be approximated as closely as it is possible from the present data.

Referring to the diagrams it is seen that the safety line of precipitation in northern Idaho and north central Montana is about 2 inches per month from June through September. This is shown very clearly for May, June, and July in northern Idaho, 1914, and for the entire summer 1918 for north central Montana.

It is seen further that the quantity of winter snowfall or total precipitation bears little relation to fires during the following summer. The great quantity of snow during winter of 1917 and a precipitation about normal until May did not stave off a very bad season, which began as soon as the rainfall fell below 2 inches.

It may be well to fix our attention to the months of May and June for a little closer consideration. June does not show a critical fire situation, provided May has

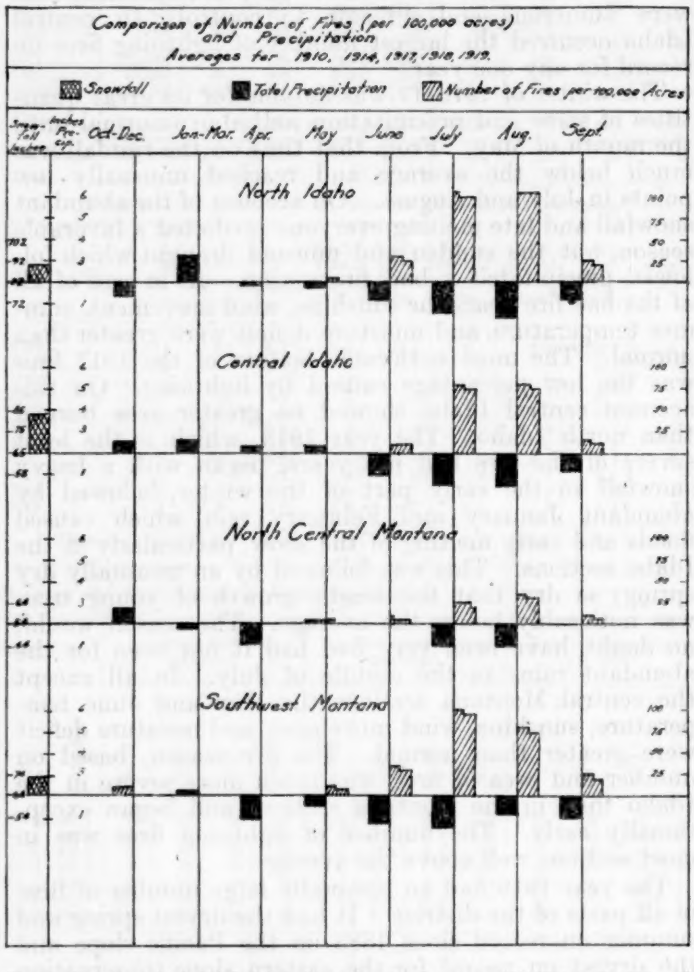

FIG. 9.—Relation of rainfall deficit to forest fires for the years 1910, 1914, 1917, 1918, and 1919, in north Idaho, central Idaho, north-central and southwest Montana.

about 2 inches of rainfall. The year 1919 shows somewhat of an exception, and the explanation lies most likely in the fact that June, 1919 had 88 per cent sunshine compared with an average of 68 per cent and because neither the spring rains nor the water from the melted snow soaked into the frozen ground. If, on the other hand, May shows a considerable deficit, and this continues throughout June, there will be many fires in June. If, as in the case of 1918, both the April and May rainfall is considerably below 2 inches, a dry June will bring on many fires.

In Figure 9 are shown the relations between the deficit in precipitation and the number of fires per month. According to averages for 1910, 1914, 1917, 1918, and 1919, the relations are quite regular. From the data it is possible to derive a figure which, when multiplied by

the difference expressed by (2 − actual rainfall for the month), approximates the number of fires for that month. For north Idaho this multiplier is 10 for May, 30 for June, 100 for July and August, and 30 for September; e. g., in north Idaho the June deficit (Fig. 9) is 1.60 inches. This multiplied by 30 equals 48. The average number of fires for that month is 53. The factor 10, 30, 100, etc., is obtained from the actual records of the number of fires by formula

$$2 - \text{actual precipitation} = \frac{\text{number of fires}}{x}.$$

experiment station and covered 1,200 acres in one afternoon. On August 19, very serious forest fires occurred on most of the north Idaho forests.

It is of interest to note that the records for Spokane, Wash., also show unusually high temperature and low humidity and somewhat increased pressure at these times, but the wind there and at the Forest Service lookout stations show no very unusual movement.

The periods of high pressure and clear sunny weather, when the daily air temperatures approach 100° F. and when the relative humidity is very low in the afternoon, present very critical weather for forest fires.

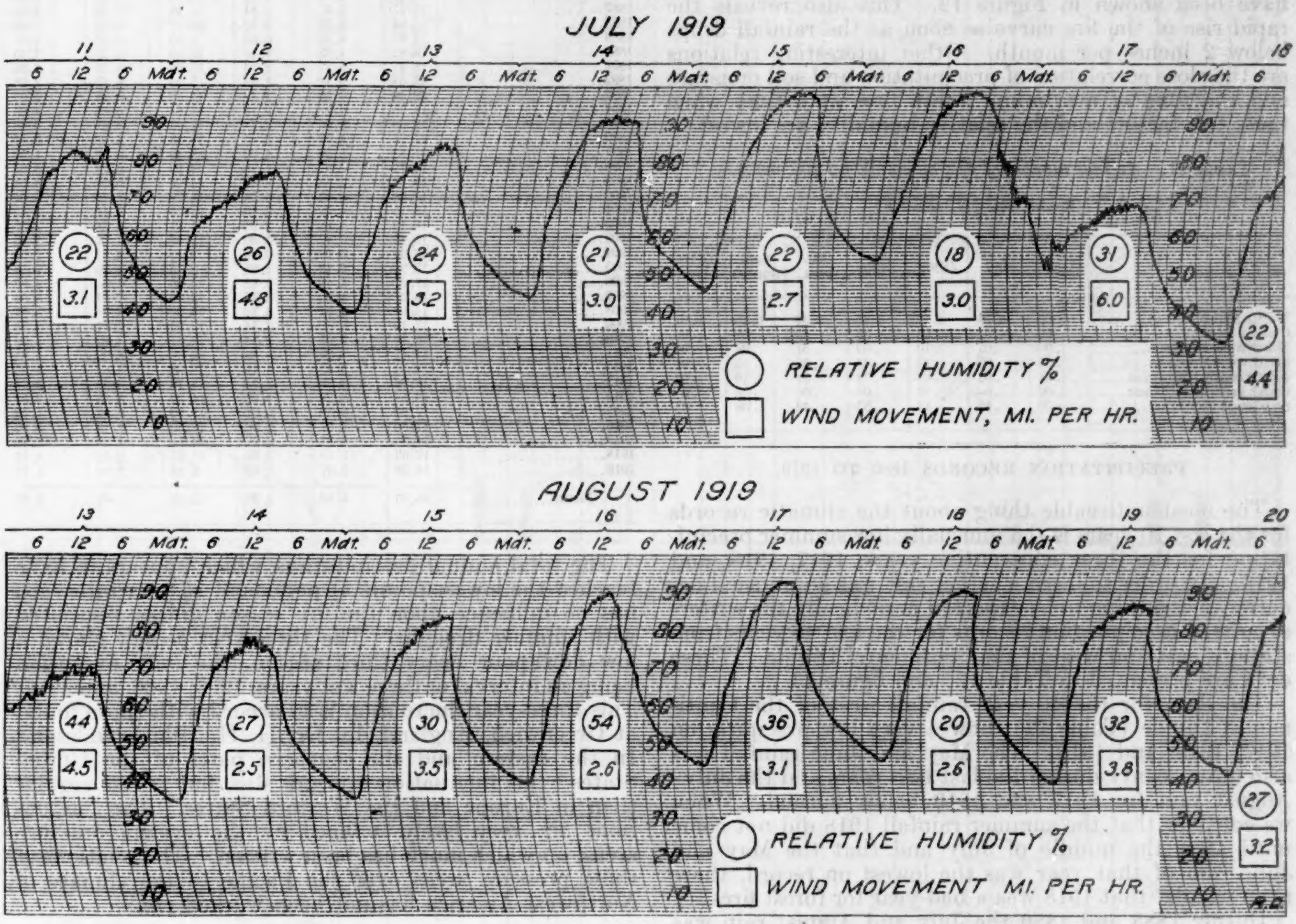

FIG. 10.—Daily rise in air temperature and lowering of relative humidity culminating in critical weather for forest fires, Priest River Forest Experiment Station, 1919.

ESPECIALLY DANGEROUS WEATHER FOR FOREST FIRES.[3]

The geographic and topographic relations which have been discussed above, and the prevalence of high-pressure areas bring about clear, warm, dry weather in summer in northern Idaho during July and August. At certain periods during these months, the weather conditions frequently approach a climax of high air temperature and low relative humidity. Examples of this are available from weather records at the Priest River Forest Experiment Station and fire records, July 11 to 19, 1919, and from August 13 to 20, 1919. The temperature curves in Figure 10 show this very clearly. On July 18, a serious fire broke out in a slashing five miles away from the

[3] Mr. Edw. A. Beals has given a very interesting discussion on weather conditions attending three great forest fires, Baudette, Columbia, 1902, and Idaho, 1910, in the February Mo. WEATHER REV. Feb., 1914, 43: 111-119.

LENGTH AND INTENSITY OF THE FIRE SEASON.

The numbers of fires in each section of the district have been averaged by months to show relatively the time of beginning and ending of forest fires, the month of greatest intensity, and the relations of air temperature and precipitation to the fires. (See Table II and Fig. 11.)

North central Montana appears to have the longest fire season. It begins in April and ends in October. April fires occur also in the two western Montana groups. In central Montana these early fires occur chiefly in the dry grass or the slash left over from the preceding fall or winter. There is no appreciable difference between the groups in air temperature. Figure 11, however, shows that the April rainfall and the annual snowfall in these parts is lower than elsewhere.

Other significant points brought out by this comparison is that the period of low summer rainfall usually corresponds closely with that of the highest air temperatures, that a rainfall of less than 2 inches per month after March or April brings up the fire curve in every section, and that there is an almost direct relation between the number of fires curve and the rainfall deficit under 2 inches per month.

For a closer comparison of the different climatic factors and forest fires the climatic data for the Priest River Experiment Station and the fire data for Kaniksu National Forest, within which the station is located, have been shown in Figure 12. This also reveals the rapid rise of the fire curve as soon as the rainfall drops below 2 inches per month. Other interesting relations are the close correlation of precipitation and soil moisture and the time of maximum forest fires at a time when these two factors and the relative humidity are lowest.

TABLE 11.—*Average number of fires by month per 100,000 acres.*

[Record 1909–1919, inclusive.]

	April.	May.	June.	July.	August.	September	October.
North Idaho	0.00	0.01	0.12	0.46	0.59	0.15	0.01
Central Idaho	.00	.0+	.03	.36	.39	.09	.00
Northwest Montana	.0+	.02	.10	.59	.51	.08	.01
Southwest Montana	.01	.03	.13	.43	.50	.16	.01
North central Montana	.01	.02	.04	.14	.21	.10	.02
South central Montana	.00	.0+	.01	.05	.06	.03	.0+
Southeast Montana	.00	.05	.11	.35	.49	.08	03

PRECIPITATION RECORDS 1880 TO 1919.

The most noticeable thing about the climatic records for the last 10 years is the unusually low summer precipitation for the three consecutive years, 1917, 1918, and 1919. In order to learn whether this was an unusual occurrence or a thing to be expected periodically the writers examined precipitation records for the last 40 years from stations east and west of the Continental Divide. These data are presented in Table 12[4] and figure 13.

The data for the 40-year rainfall west of the Continental Divide (Table 12) show a very low precipitation 1917, 1918, and 1919. The May and June rainfall was also quite scanty during the last two years and the July–August rain for 1917 and 1919 below normal. When we consider that the summer rainfall 1918 did not come until after the middle of July and that the May and June rain of that year was the lowest on record, there is no wonder that 1918 was a bad year for forest fires.

During 1888 and 1889 the July and August rain was also very low, but the records show at that time considerable May and June rain. The year 1889 is remembered as one of the very worst fire seasons in the Pacific Northwest.

Records for 1910 do not indicate such very critical conditions as the fire records would have us believe. During that year there was almost no June and July rain, and the fire season, though very intense, was limited to the first three weeks in August, during a period of high wind and air temperature.

East of the Continental Divide the annual precipitation for 1919 was the lowest since 1889 and the combined May–June and July–August rainfall the lowest on record.

[4] The averages for the Pacific slope are made from the records of Spokane, Missoula, and Walla Walla and for the eastern slope from Helena, Havre, and Miles City.

TABLE 12.—*Precipitation on the Pacific slope and eastern slope, 1880 to 1920.*

Year.	Pacific slope.[4] (Averages.)			Eastern slope.[4] (Averages.)		
	Annual.	May-June.	July-August.	Annual.	May-June.	July-August.
1880	[1] [17.71]	4.53	2.90	13.41	5.13	3.87
1881	22.50	3.91	2.85	15.64	5.46	4.88
1882	20.03	4.75	3.12	11.07	4.71	3.42
1883	13.47	3.21	[1 0.18]	12.08	3.70	2.69
1884	20.59	4.62	[1 2.90]	18.33	5.99	4.94
1885	17.16	5.78	1.03	9.87	6.02	2.52
1886	15.81	2.95	1.29	12.42	5.60	2.09
1887	17.97	5.37	2.81	14.94	7.88	3.99
1888	15.64	4.53	0.32	12.37	6.04	2.66
1889	12.65	4.32	0.59	8.80	3.07	2.57
1890	13.92	4.33	1.45	10.03	4.25	2.43
1891	18.41	5.31	2.84	16.65	8.29	4.55
1892	15.68	5.16	1.44	13.05	6.53	2.90
1893	22.48	6.59	2.38	14.32	5.83	3.93
1894	17.76	3.98	2.13	13.84	6.36	2.03
1895	12.68	3.00	2.48	11.46	4.80	2.85
1896	17.75	4.62	2.46	14.53	6.20	3.17
1897	21.83	5.30	4.00	13.49	5.59	1.90
1898	14.79	5.47	1.78	13.99	6.23	3.01
1899	19.79	3.63	3.57	14.97	6.27	3.54
1900	17.66	6.02	3.04	11.20	3.43	4.86
1901	15.15	4.42	2.10	14.55	7.11	4.42
1902	18.19	4.99	2.95	11.21	6.38	2.50
1903	15.49	3.47	3.69	12.46	4.27	5.86
1904	13.62	3.09	0.99	8.45	3.81	1.57
1905	15.90	6.43	1.91	9.75	4.79	3.58
1906	17.67	5.46	1.42	15.00	7.60	3.08
1907	16.27	4.02	3.35	13.59	7.21	3.04
1908	14.04	4.77	3.33	16.90	8.76	3.51
1909	17.10	3.50	3.54	15.35	6.81	4.64
1910	15.16	3.05	2.34	11.61	4.02	3.09
1911	12.41	4.29	1.86	16.39	5.29	5.94
1912	18.54	5.49	4.49	15.68	6.67	4.93
1913	17.06	4.89	2.12	13.78	5.53	3.73
1914	13.58	4.28	1.96	14.29	5.83	3.51
1915	17.20	6.82	3.01	17.60	6.92	7.13
1916	17.80	5.67	2.00	18.50	7.13	5.90
1917	14.54	4.35	0.77	13.71	4.84	2.86
1918	12.63	1.50	2.99	11.31	2.92	4.75
1919	14.20	2.07	1.40	9.18	2.60	1.78
Mean	16.63	4.50	2.29	13.50	5.64	3.61

The total annual precipitation, which appears to have reached the lowest points at periods of 15-year intervals, has no influence upon the fire season unless associated with summer drought. The three-year seesaw shows a low downpour every third season, the only exception being an interval of three wet years, 1905, 1906, and 1907. This three-year fluctuation is in accord with those found at Greenwich, England, by Dr. H. H. Hildebrandsson.[5] In the eastern and the southern parts of the United States[6] this fluctuation appears also, but is less regular than in Europe and the Western States. The fluctuations are very likely induced by the oceanic-pressure areas, on which much has been written. The relations of these pressure areas over the Pacific to the climate of Northwest America has not been worked out.

CHANCES OF PREDICTING DANGEROUS WEATHER CONDITIONS.

It should be remembered that since the atmospheric pressure areas require but one day to travel from the Pacific coast to the Rocky Mountains, and since there are no permanent weather stations to the west of the Pacific coast, it is evident that the basis for forecasting weather in the Northwestern States is largely wanting.

The data presented should have their value in deciding upon distribution of men and funds for fire protection.

[5] Cycles of Sun and Weather: *Nature*, April, 1912, p. 147.

[6] Secular Variations of Precipitation in the United States, by Alfred J. Henry, *Bulletin American Geographical Society*, Vol. XLVI, March, 1914. See also the articles by C. F. Brooks, Heryk Arctowsky, F. Nansen, H. Hildebrandsson, H. F. Blanford, E. Huntinton, and A. Schuster, on Pressure, Sunspots, and Climatic Controls.

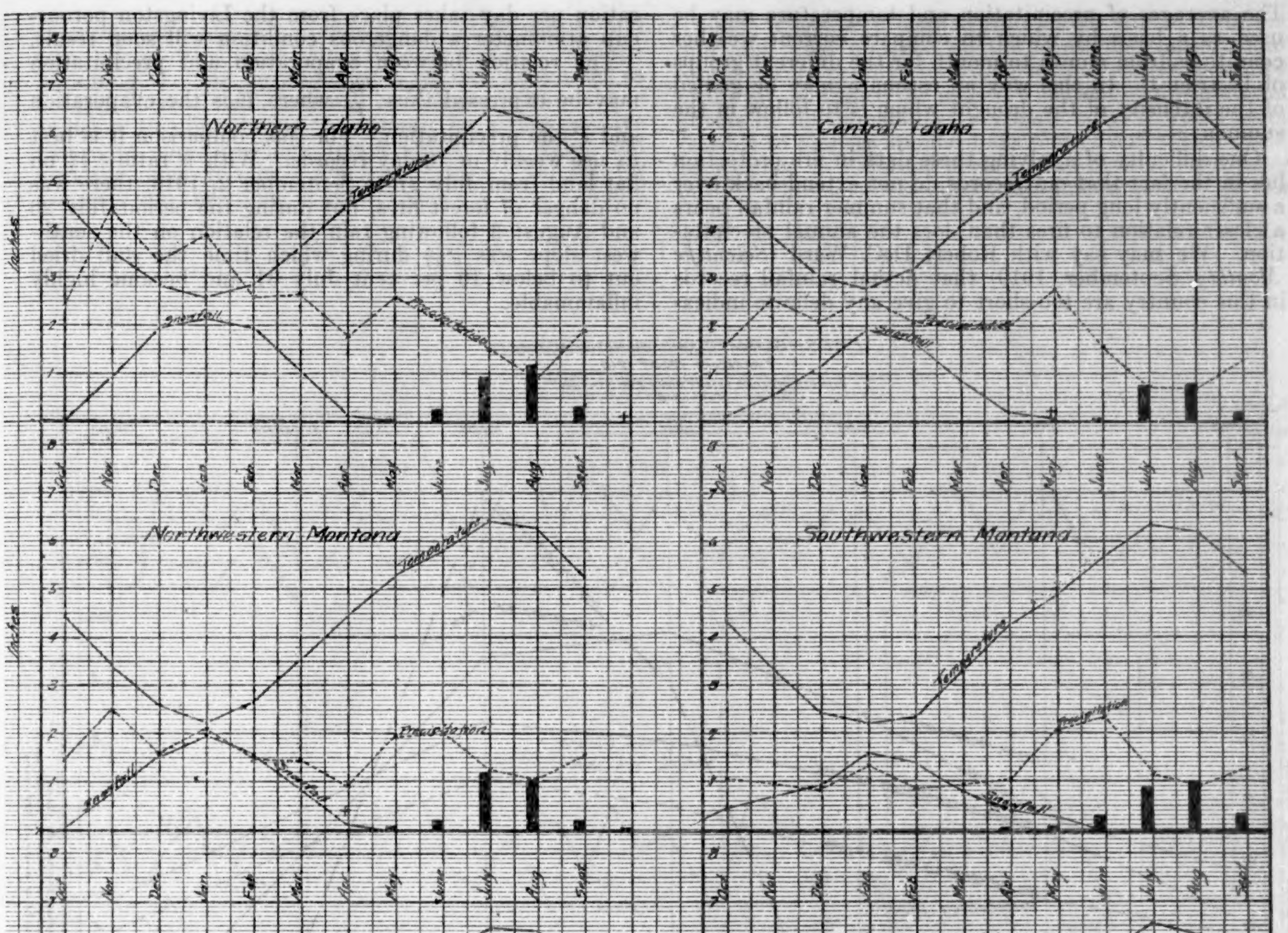

FIG. 11.—Relation between forest fires, precipitation, and air temperature for the seven climatic sections of Montana and north Idaho.

The averages of precipitation and temperature may be used as a basis by which to compare current weather conditions from month to month for the different groups of District 1. In this way an estimate may be gained of the intensity of the drought which is to follow in the summer.

One difficulty of applying these data in fire protection lies in the fact that our records do not extend back over a sufficiently long period, and that summer rainfall bears a closer relation to fires than does the annual precipitation. We may say with Robert DeC. Ward (*Scientific Monthly*, September, 1919) that actual rainfall records in this country are too short to give any definite indication of secular variations. The longest records cover 100 years, and a few stations have records of more than 50 years in length. While a study of these records shows a more or less definite and recognizable long-period fluctuation, they appear to be largely localized, and no definite conclusions can be drawn for extended areas.

There are several ways of keeping informed regarding the weather conditions. From records of evaporation at the Priest River Forest Experiment Station for several years it appeared that if the evaporation from a free water surface is more than five times the amount of precipitation, dangerous conditions will soon follow, or if an average of more than 25 cubic centimeters of evaporation per day takes place from the Livingston porous-cup atmometer a dangerous condition will soon result.

The relation between evaporation and precipitation may be expressed thus: $\frac{E}{P}$, where E is the evaporation and P the precipitation. For this comparison it is best to use weekly or 10-day records. With a ratio $\frac{4.59}{1.12}$ on flat land from July 27 to September 2, 1916, there was no danger of forest fires, but during the period July 20 and August 3 following rain the relation on the southwest slope was $\frac{2.21}{0.61}$ during which time the duff dried out to below 10 per cent July 31 and became highly inflammable.

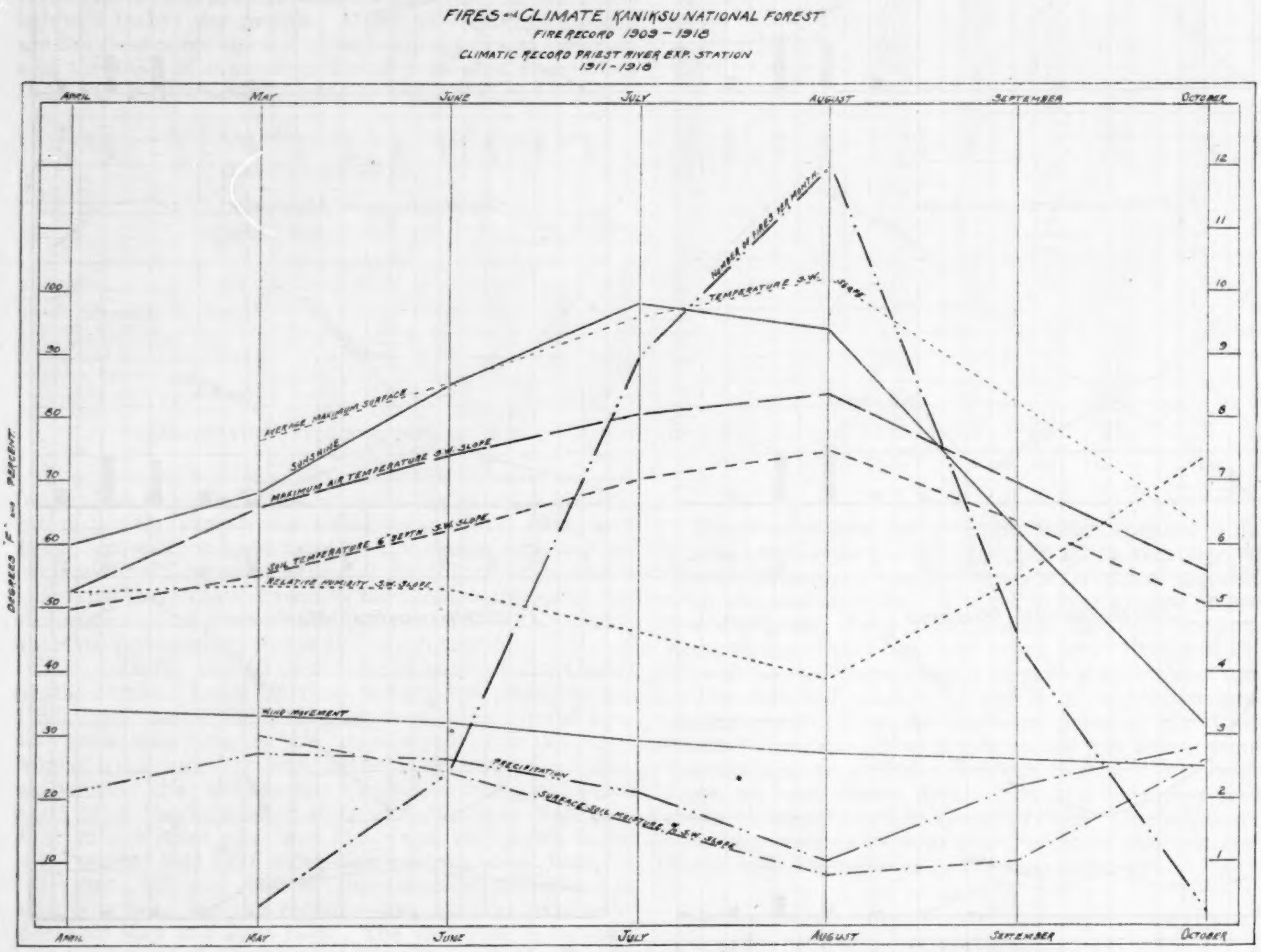

FIG. 12.—Relation between weather and forest fires on the Kaniksu National Forest in north Idaho, 1911-1918, inclusive.

By sampling duff and litter of the forest floor during the summer months and applying burning tests it was found that this material would burn and the fire travel if the moisture content was below 10 per cent measured by its dry weight. Though this is a direct method, it requires much work in sampling, drying, weighing, and calculation, which can not be conducted easily or without considerable equipment.

Another method, which has been suggested by Mr. E. H. Finlyson, of the Canadian Forest Service, holds much promise especially because of its simplicity, ease of observation, and current daily application. It consists in giving certain positive and negative values to all of the

climatic elements, such as sunshine, wind, humidity, and rain. By plotting these values for each day, say from the beginning of June, beginning at a red line, designated as neutral, current conditions will be indicated either above or below this line during the summer by giving positive values to sunshine, high temperature, and wind, and negative values to rain or low temperature. The test for accuracy and the giving of correct values to each climatic factor is in returning to the neutral line as soon as there is no fire danger. Several years' record will be needed before the correct values are obtained.

To make this method more effective, one could measure evaporation from free water surfaces and, if desired, measure the intensity of solar radiation by the black and white porous porcelain atmometer cups designed by Dr. B. E. Livingston. It should be stated that maximum air temperatures, the relative humidity at 5 or 6 p. m., and the amount of evaporation will undoubtedly come closer than any other factors of climate in pointing out the seriousness of the situation.

Current records for any one place are of no value unless compared with data for the same place during previous seasons.

Since it has been learned from closer studies that the duff and other material on the forest floor absorb and lose moisture readily, according to the relative humidity of the air, and since the moisture content of this material affects its inflammability very materially, it would seem feasible to prepare standard samples of duff which could be weighed in different parts of the district simultaneously. The moisture content and inflammability of this material may readily be indicated by tabular data prepared at a forest experiment station.

In any event it will be necessary, in order to have a good idea of the current climatic status, to keep close watch of the conditions from month to month, both by instruments, by general observation, and by reports from the field, and to employ some instrumental method for a closer record from day to day and week to week.

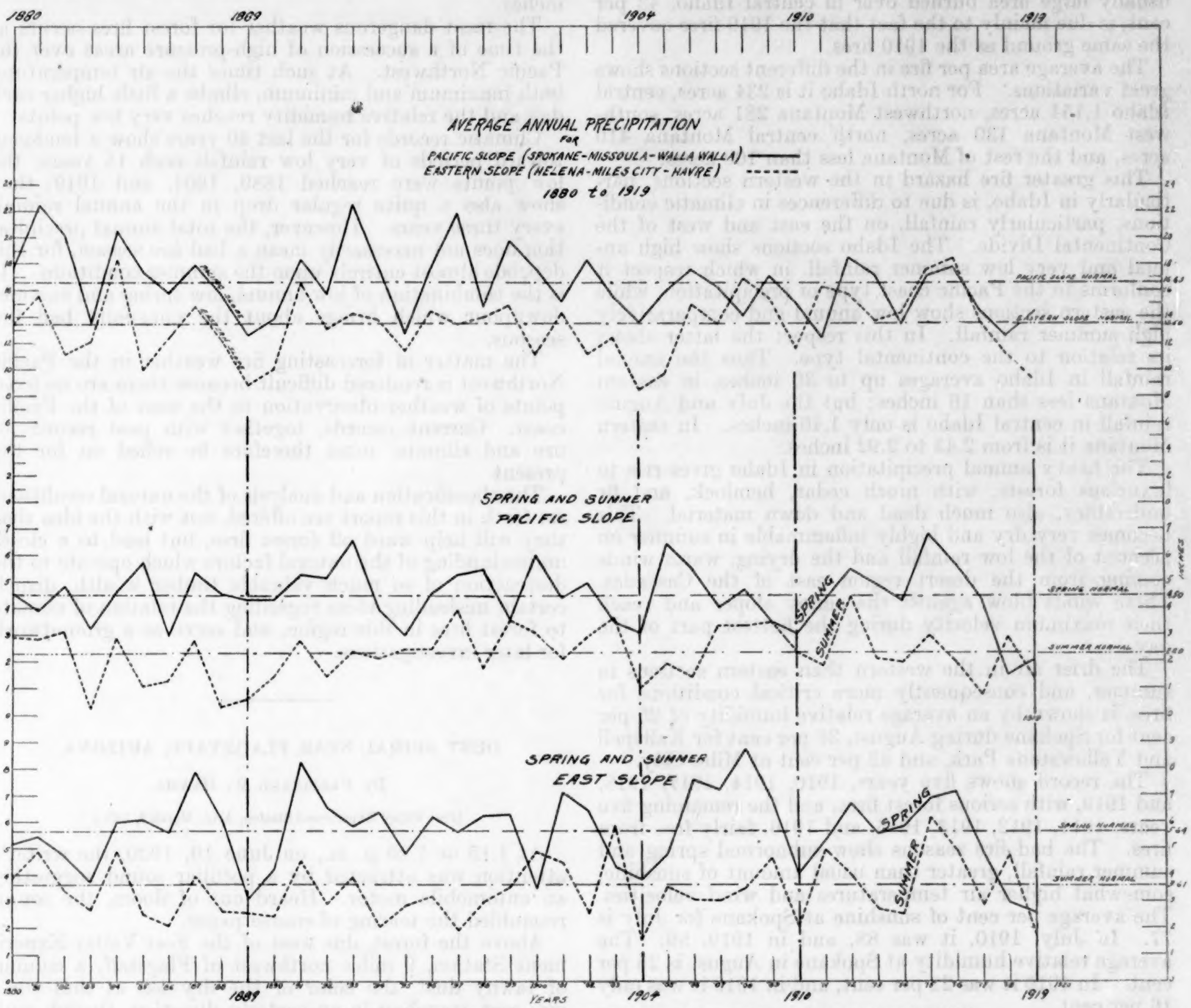

FIG. 13.—Precipitation records for three Pacific slope stations and three continental slope stations, 1880-1919.

SUMMARY AND CONCLUSIONS.

Montana and north Idaho were divided into seven smaller climatic and topographic sections for close comparison between forest fires and climatic records, 1909 to 1919, inclusive.

The comparison brings out that in this region an average of nearly 15 per cent of the area of the national forests has burned over since 1909. The sections west of the Continental Divide have suffered much greater damage than the eastern parts. On the north Idaho forests the fires covered 17 per cent of the area, in northwest Montana 19 per cent, while the eastern sections are all below 8 per cent, some less than 1 per cent. The unusually large area burned over in central Idaho, 43 per cent, is due mainly to the fact that the 1919 fires covered the same ground as the 1910 fires.

The average area per fire in the different sections shows great variations. For north Idaho it is 234 acres, central Idaho 1,154 acres, northwest Montana 281 acres, southwest Montana 130 acres, north central Montana 410 acres, and the rest of Montana less than 100 acres.

This greater fire hazard in the western sections, particularly in Idaho, is due to differences in climatic conditions, particularly rainfall, on the east and west of the Continental Divide. The Idaho sections show high annual and very low summer rainfall, in which respect it conforms to the Pacific coast type of precipitation, while the eastern sections show low annual and comparatively high summer rainfall. In this respect the latter shows its relation to the continental type. Thus the annual rainfall in Idaho averages up to 30 inches, in eastern Montana less than 16 inches; but the July and August rainfall in central Idaho is only 1.40 inches. In eastern Montana it is from 2.43 to 2.92 inches.

The heavy annual precipitation in Idaho gives rise to luxurious forests, with much cedar, hemlock, and fir understory, also much dead and down material. This becomes very dry and highly inflammable in summer on account of the low rainfall and the drying, warm winds coming from the desert region east of the Cascades. These winds blow against the sunny slopes and reach their maximum velocity during the hottest part of the day.

The drier air in the western than eastern sections in summer, and consequently more critical conditions for fires, is shown by an average relative humidity of 25 per cent for Spokane during August, 36 per cent for Kalispell and Yellowstone Park, and 42 per cent at Miles City.

The record shows five years, 1910, 1914, 1917, 1918, and 1919, with serious forest fires, and the remaining five years, 1911, 1912, 1913, 1915, and 1916, fairly free from fires. The bad fire seasons show subnormal spring and summer rainfall, greater than usual amount of sunshine, somewhat higher air temperatures and wind velocities. The average per cent of sunshine at Spokane for July is 77. In July, 1910, it was 88, and in 1919, 89. The average relative humidity at Spokane in August is 25 per cent. In 1910 it was 22 per cent, and in 1919 it was only 16 per cent.

More lightning fires have occurred in central and north Idaho than in the other sections; central Idaho shows a total of 33 per each 100,000 acres in 10 years, north Idaho 23, western Montana 13 each, south-central Montana 2, and southeast Montana 10.8.

The causes of the unusual forest-fire situation during the summer 1919, the worst since 1910, are most likely due to a combination of unusual weather conditions—frozen ground in the fall, so that little moisture went into the ground at the time of melting in spring; much melting of the snow in late December; light winter precipitation; early spring rains most likely fell on the snow in the back woods and therefore did not soak into the ground; very light spring and summer rains. This season, moreover, was the third in a succession of dry summers.

A comparison of climate and fires by months brings out the fact that it is necessary to have at least 2 inches of rainfall for each month in summer to allay forest fires. The average rainfall in the Idaho and western Montana sections are lower than this amount; central Idaho, June, 1.56; July, 0.10; August, 0.70; north-central Montana section shows June, 3; July, 1.72; August, 1.20; south-central Montana, June, 2.46; July, 1.37; August, 1.06 inches.

The most dangerous weather for forest fires occurs at the time of a succession of high-pressure areas over the Pacific Northwest. At such times the air temperature, both maximum and minimum, climbs a little higher each day and the relative humidity reaches very low points.

Climatic records for the last 40 years show a tendency toward periods of very low rainfall each 15 years; the low points were reached 1889, 1904, and 1919; they show also a quite regular drop in the annual rainfall every three years. However, the total annual precipitation does not necessarily mean a bad fire season, for this depends almost entirely upon the summer conditions. It is the combination of low annual, low spring and summer downpour which brings about the unusually bad fire seasons.

The matter of forecasting fire weather in the Pacific Northwest is rendered difficult because there are no fixed points of weather observation to the west of the Pacific coast. Current records, together with past records of fire and climate, must therefore be relied on for the present.

The classification and analysis of the natural conditions set forth in this report are offered, not with the idea that they will help ward off forest fires, but lead to a closer understanding of the natural factors which operate to the destruction of so much valuable timber wealth, dispell certain misleading ideas regarding the relation of climate to forest fires in this region, and serve as a groundwork for later investigations.

DUST SPIRAL NEAR FLAGSTAFF, ARIZONA.

By FERDINAND W. HAASIS.

[Fort Valley Experiment Station, Ariz., March 6, 1922.]

At 1.15 or 1.20 p. m., on June 19, 1920, the writer's attention was attracted by a peculiar sound suggesting an automobile motor. Heard out of doors, the sound resembled the tearing of coarse paper.

Above the forest, due west of the Fort Valley Experiment Station, 9 miles northwest of Flagstaff, a column of tawny dust, the color of the dry soil at that time, was seen traveling in an easterly direction, though with minor deviations, and forming a somewhat undulating band in the general direction of the sun. From below it appeared to be a nearly vertical spiral so close to the sun that the upper part could be seen only with great difficulty. The column was intermittent, sometimes almost wholly disappearing, at which time the characteristic noise subsided also. The height was difficult to estimate; perhaps 500 feet, perhaps 1,000.

When about 500 feet west of the west fence of the station grounds it broke off to the southeast downhill, and whirled around near the back corral. It oscillated on this flat for a time, apparently moving first southeast, then northwest, possibly in a circle, or in other directions. At one time it seemed to be starting to move north or northeast directly toward the station buildings. The

THE CLIMATIC PROVINCES OF THE EARTH

(After Köppen, Petermanns Mitt, 1918, Pl. 10)

Scale 1:87 000 000

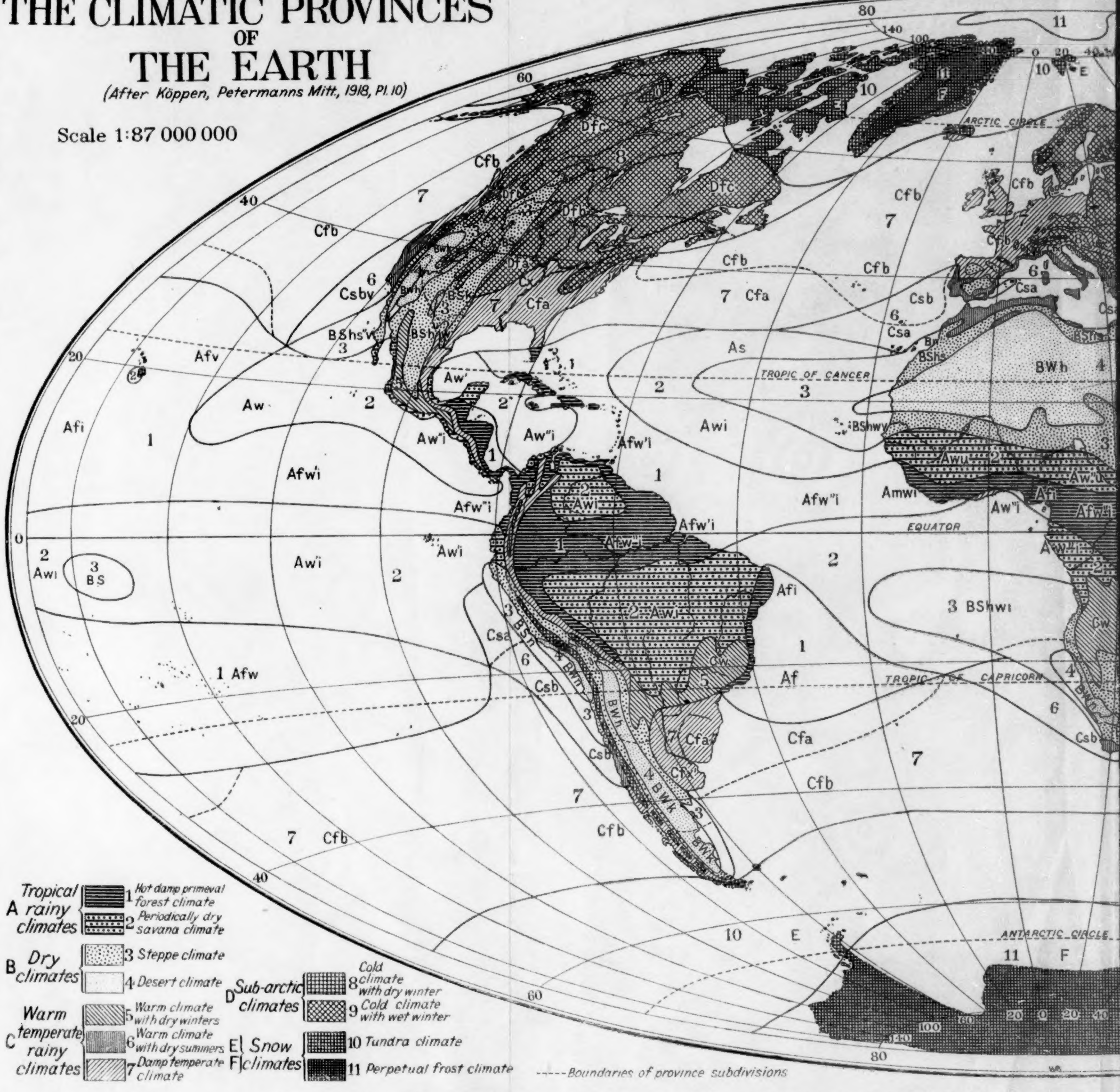

FIG. 1.—Köppen's map of the climatic provinces of the earth. (Courtesy of the *Geographical Review*, published by the American Geographical Society, Br

98186. (To face page 69.)

The Geographical Review, Vol. VIII, No. 3, 1919, Pl. II

S steppe climate, reduced rainfall amount 25 to 50 cms.
W desert " " " " under 25 cms.
a temperature of warmest month > 22°C.
b " " " " < 22°C., more than 4 mos > 10°C.
c " of only 1 to 4 mos. > 10°C., coldest mo. > -36°C.
d " " " " " " " > 10°C., " " ≤ -36°C.
f constantly moist (enough rain or snow in all months)
g Ganges type of annual variation of temperature, with maximum before summer rainy season.
h hot, with mean annual temperature > 18°C.
i isothermal; difference between extreme months < 5°C
k winters cold, mean annual temperature < 18°C., warmest month > 18°C.
k' winters cold, mean annual temperature < 18°C. warmest month < 18°C.

m monsoon rains, virgin forest climate in spite of dry season
n frequent fog
n' fog infrequent, but high humidity with rainlessness and relatively cool (summer < 24°C.)
p fog infrequent, but high humidity with very high temperature (summer > 28°C., Persian G. etc.)
p' fog infrequent, but high humidity with summer temperatures 24° to 28°C. (Gabes to Alexandria)
s driest season in summer of that hemisphere
w " " " winter " " "
s w' the same, rainy season shifted into autumn
s" w" " " " " in two parts, with short dry season intervening.
u (reversed) Sudan type of temperature variation, with coolest month after the summer solstice
v Cape Verde " " " " " warmest season shifted into autumn

aphical Society, Broadway at 156th Street, New York.) NOTE.—The numbers 8 and 9 in the legend for "D-sub-Arctic climates" should be interchanged.

basal diameter, judged from a distance of about 300 feet, was from 10 to 15 feet. Leaves and trash were included in the swirl for a height of not less than 5 or 10 feet, resulting in a dense blackish cloud to this height. Had the whirl been observed from above, its rotation would have appeared counterclockwise. When south of the observer the column still seemed to lie in the general direction of the sun, although probably mainly *ahead* of the position of the ground end.

The spiral died out on a rocky point about 500 feet south of the back corral at about 1.25 p. m., the upper part of the dust column floating for some time after the ground swirl had disappeared.

The wind about noon had been variable—northwest, north, northeast, and east. The northwest and east winds are less common here than those from other directions. At about 1:25 p. m., there was almost no wind on the station grounds. The day was clear and hot with a maximum shade temperature of 81° at 2 p. m., and 80° at the time of the phenomenon.

Section 21 is a cutover area with few trees now standing, and it is possible that the whirlwind originated there. The soil over this area is mainly residual from basaltic rock, is scantily covered with vegetation, and bakes badly when exposed to the sun, thus reflecting a large amount of heat.

KÖPPEN'S CLASSIFICATION OF CLIMATES: A REVIEW.

By PRESTON E. JAMES.

[Clark University, Worcester, Mass., March 15, 1922.]

One of the most important contributions to the subject of climatic regions is that of Dr. Wladimir Köppen, published in Germany in 1918.[1] This classification is revised and remodeled from an earlier one, proposed in 1901, and largely based on vegetation zones. In the revised scheme (see Fig. 1), the general plan of the vegetation zones may still be seen, but in determining his boundaries he now uses the decisive climatic criteria which are fundamental in the distribution of vegetation. Köppen includes in the diagrams accompanying his article a map of an ideal continent without relief (see Fig. 2). On this he places his climatic regions, drawn as they theoretically would lie if relief and irregularity of land and water were eliminated. An explanation of the departures from the ideal scheme in the several continents would make a profitable study for university students who have sufficient preparation.

This classification has not been made available in English for detailed use. It was reviewed by Professor Ward[2], who also reproduced Köppen's map in black and white. But a detailed statement of the criteria for the subdivisions is not available. It is this want, which the present reviewer hopes to fill.

GENERAL PRINCIPLES USED.

When we consider the distribution of climates in general over the earth, it may be seen that the regions of maximum human development lie between two desert regions—the deserts of ice, and the deserts of sand. In these deserts life is negligible, although the cold regions are far more hostile than the hot deserts, since in the latter every shower may awaken the germs of life, and man may encroach on their boundaries by the use or irrigation. But between them, broadly speaking, human development of a high order is confined. These regions, therefore, may be taken as the supports, so to speak, of the system. They merge into the "life zone" by transition types, the tundra and the steppe, respectively. In the deserts vegetation is lacking; in the transition types we find low bushes and grass; elsewhere trees grow to considerable heights.

The deserts of ice form a polar cap, drawing a limit beyond which there is no life; but the deserts of sand lie in two girdles about latitude 30° north and south, and are separated by a constantly rainy climate along the Equator. Furthermore, since these deserts lie in the trade-wind belts,[3] they are driest on the lee coasts, and are interrupted by more humid regions on the eastern, or windward, sides of the continents.

The regions not included in these two big types and their transition zones are divided as follows: (1) The winterless region, which lies between the deserts of sand along the Equator; (2) the warm temperate region; (3) the sub-Arctic region. Since the latter does not occur in the Southern Hemisphere, the term sub-Arctic is permissible.

These three regions are again subdivided on the basis of rainfall distribution, as in the following table:

1. Winterless region.
   (*a*) Constantly rainy climate.
   (*b*) Periodically dry climate.
2. Warm temperate region.
   (*a*) Dry season absent.
   (*b*) Dry season in winter.
   (*c*) Dry season in summer.
3. Sub-Arctic region.
   (*a*) Dry season absent.
   (*b*) Dry season in winter.

It can be seen that 1 and 3 are divided into only two regions each, while 2 is divided into three. In the Tropics the total variation of temperature is so slight that it is unimportant in what season the rain comes, so that it is sufficient to distinguish between a constantly rainy and a periodically dry climate. In the sub-Arctic region there is no example of a dry season in summer, so that the first two divisions of the warm temperate region may be used farther north also.

The combination of these types results in 11 climatic regions. These 11 regions are applied to the earth, and given the numbers as in the following table:

1. Tropical rainy forest climate	A. Tropical rainy climates.
2. Periodically dry savanna climate	
3. Steppe climate	B. Dry climates.
4. Desert climate	
5. Warm climate with dry winters	C. Warm, temperate rainy climates.
6. Warm climate with dry summers	
7. Damp climate with mild winters	
8. Damp climate with severe winters	D. Sub-Arctic climates.
9. Cold climate with dry winters	
10. Tundra climates	E. Polar.
11. Perpetual frost climates	F. Climates.

[1] W. Köppen: Klassifikation der Klimate nach Temperatur, Niederschlag, und Jahreslauf. *Petermann's Mitteilungen*, September, October, and November-December, 1918, vol. 64, pp. 193-203, and 243-248, with map and diagrams.

[2] R. De C. Ward: A new Classification of Climates. *Geographical Review*, September 1919, vol. 8, pp. 188 to 191, with map.

[3] This statement needs some modification. The deserts of the globe are not always found in the so-called trade-wind belts, notably exceptions occurring in South America on both sides of the Andes between Peru and Patagonia; also in central Asia east of the Caspian Sea and in the southwest of the United States. Moreover, it is believed that the expression "trade winds" commonly refers to winds over a water, rather than a land surface. The regularity of the trades is disturbed by land areas and while the general direction of these winds is not greatly changed when passing from sea to land the velocity and steadiness are not the same.—*Editor*.

CRITERIA FOR DETERMINATION OF REGIONS.

With this general statement, we may now take up the actual criteria which are used to determine the boundaries of the different regions.

I. POLAR REGIONS.

The regions of cold are subdivided into perpetual-frost climates (11), and tundra climates (10). The perpetual-frost climate is one where snow and ice is a permanent condition. The isotherm of 0° [4] for the warmest month is used here, and sets off the ice sheets of Greenland and Antarctica, and the snow-capped summits of mountains.

In choosing the criteria for the tundra boundary, it should be remembered that the decisive temperature factor for organic life, including man, consists in the absence of a sufficiently cold season in low latitudes and of a sufficiently warm season at high latitudes. Neither extreme summer heat nor extreme winter cold has a similarly clear influence. Against these extremes the plant world protects itself by a period of rest. For this reason the isotherm of 10° for the warmest month was chosen as the tundra boundary, which limits approximately the poleward growth of forests.

II. ARID REGIONS.

The essential feature in these regions is the absence of surface run-off. Everywhere evaporation is greater than precipitation, and no streams may originate. Since evaporation increases with higher temperatures, it is obvious that a given amount of rainfall in a region with a mean annual temperature of 20° might be completely evaporated, whereas in a region with a mean annual temperature of 15° this same amount of rainfall might provide abundant run-off. Therefore, no fixed amount of rainfall can be taken as the arid boundary.

Furthermore, if rainfall comes altogether or largely in the colder months, less will be evaporated than if it comes in summer, so that further allowance must be made for

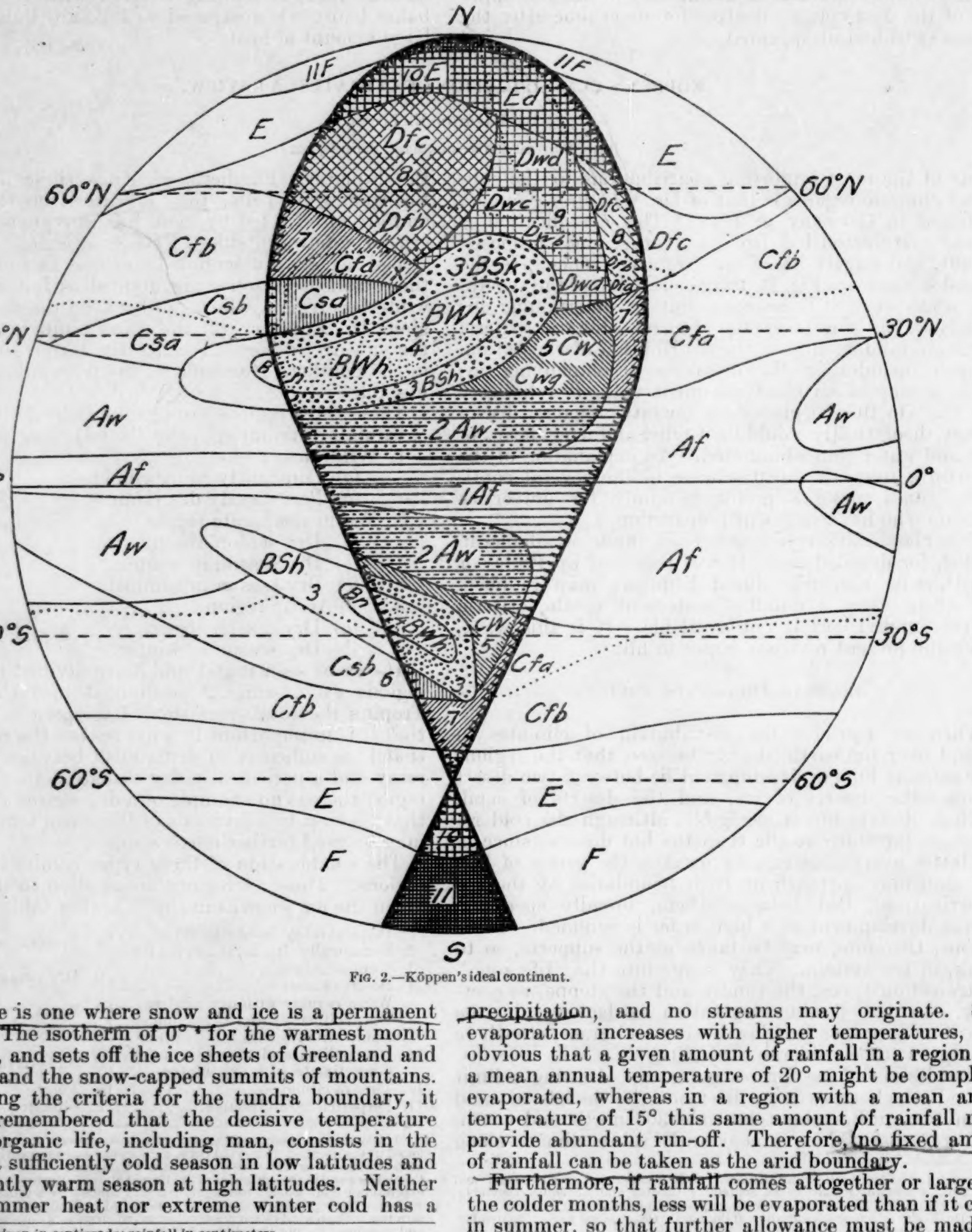

FIG. 2.—Köppen's ideal continent.

[4] Temperatures given in centigrade; rainfall in centimeters.

the season in which the rain comes. Köppen has worked out the following table for this, using the desert boundary in every case, as twice that of the steppe:

Temperature.	25° C.	25-20° C.	20-15° C.	15-10° C.	10-5° C.	5° C.
Desert boundary (cm.)	32	29	26	23	20	16
Steppe boundary (cm.)	64	58	52	46	40	32

The season in which the rain falls is considered, when there is a pronounced summer rainfall, by taking 30 per cent higher than the figure in the tables; and when there is a pronounced winter rainfall, by taking 30 per cent lower. Thus the boundaries of the desert and steppe are determined by a combination of rainfall, temperature, and seasonal rainfall distribution. The desert is region 4 on the map; the steppe is No. 3.

III.—HUMID REGIONS.

A. The Tropics.—Within the large area of forest or rainy climates, we find a great variety of conditions, according to (1) temperature, which decreases with increasing latitude or altitude; (2) according to annual ranges, which increase with greater continentality; and (3) with the occurrence of dry seasons. In the vegetable world this variety is expressed by periods of rest, sometimes due to cold, sometimes to drought.

As was mentioned above, summer heat is not as important a factor on the boundary of the Tropics, as is a season of sufficient coolness. For this reason Köppen chooses as his boundary of the tropical rainy climates, the isotherm of 18° for the coldest month. The regions thus defined are divided into types (1), where there is a constant rainfall and (2) types where there are one or two marked dry seasons in the year. In the former, the vegetation is the usual tropical rain forest, but the latter is generally characterized by a savanna or grass land. In certain regions of Type 2, however, we find a growth of tropical vegetation in spite of a sharply defined dry season. This is produced because the rainfall in the wet season gives sufficient moisture to last throughout the dry period in the ground. Where the rainfall is more than 20 centimeters, as on the Malabar coast the dry season may last as much as four months. Such conditions occur especially in monsoon regions. The rain forest may also grow along river valleys, as along the southern tributaries of the Amazon, where the moisture is supplied in abundance from the savanna uplands into the canyonlike valleys.

Grasslands, also, may appear in a constantly rainy climate where the inhabitants are accustomed to burning the savannas bordering the region, as in portions of Africa.

In this group, it is unimportant to distinguish the season in which the rain falls, since the yearly ranges of temperatures are very small. In fact, the seasons themselves are determined by the rains and not by temperature, as in the extra-tropical regions.

Since the deserts are interrupted on the eastern sides of the continents, as mentioned above, the periodically dry savanna climates may merge directly with the warm temperate regions. But whatever the adjoining region may be, the boundary of the Tropics is always taken as the isotherm of 18° for the coldest month.

2. *Warm temperate group.*—The arrangement in the Temperate Zone is complicated because in this case it makes an essential difference whether the rainy season comes in the cold or in the warm part of the year. Therefore, there are three warm temperate climates: Rainy summers (5); rainy winters (6); constantly moist (7).

Climate 5 is a continental type with a summer maximum of rainfall. It is bounded toward the Equator by the isotherm of 18° for the coldest month. It is distinguished from 6 and 7 by the rainy season: the rainiest month of the warm season brings 10 times as much rainfall as the driest month of the cold season.

Climate 6 is the well-known Mediterranean climate, sometimes known as the subtropical type, which is so well developed on the west coasts of the continents in the Horse Latitudes. As its name inplies, the best example is in the Mediterranean countries but it also reappears in characteristic form in California, Chile, Cape Town, and southwest Australia. This is a marine type with winter rainfall. Since evaporation is less than in Type 5, owing to the low-sun character of its rainy season, the region includes only those areas where the rainiest month of the cold season brings three times as much rain as the driest month of the warm season.

Climate 7 is a characteristic east coast type, in which there is sufficient rain in all seasons, so that it is not classed in either of the foregoing.

3. *Sub-Arctic group.*—The sub-Arctic climates are separated from the warm temperate climates on the basis of a regular annual snow covering for a period of several weeks. This snow blanket is a very important factor in vegetation. The isotherm which coincides with the southern boundary of such a snow blanket in regions of sufficient humidity is that of −2° for the coldest month. The term sub-Arctic is permissible for this group, since in southern South America—the only southern hemisphere continent which lies near enough to the pole to reach such climates—the isotherm of 10° for the warmest month (the equatorial margin of the tundra) lies farther from the pole than the isotherm of −2° for the coldest month. This is due to the marine type of the southern Temperate Zone, with its resulting small ranges, and is illustrated by the temperatures at Cape Horn (January, 9. 1° C.; July, 0.1). ?

Climate 8 is one in which rain or snow occurs in all months and is similar in this respect to climate 7 of the previous group. It is distinguished from 7 only on the basis of a regular snow covering in winter.

Climate 9 is an extreme continental type, occurring only in central Siberia. Here the region with a distinct summer maximum rainfall, and with rainless winters, is set off as distinct from Type 8. These clear, winter skies give us the conditions for the maximum of winter radiation, just as the hot deserts give us the maximum of high-sun insolation.

CLIMATIC SYMBOLS.

In addition to his division of the earth into the foregoing regions, Köppen enriches his map with a series of climatic symbols, indicating the variations and special developments which are found within the more general regions. These symbols need no discussion, but are translated in the following table:

(*a*) Mean temperature of the warmest month over 22°. (71.6°F)
(*b*) Mean temperature of the warmest month under 22°, at least four months over 10°.
(*c*) Only one to four months over 10°, coldest month over −36°.
(*d*) The same, but coldest month under −36°.
(*f*) Constantly moist (sufficient rain or snow in all months).
(*g*) Ganges type of annual temperature range with maximum before the turn of the sun and the summer rainy season.

(*h*) Hot, annual temperature above 18°.
(*i*) Isothermal, difference between extreme months less than 5°.
(*k*) Cold winter, annual temperature below 18°, warmest month above 18°.
(*k'*) The same, excepting warmest month below 18°.
(*m*) Monsoon rains, primeval forest in spite of one dry period.
(*n*) Frequent fogs.
(*n'*) Infrequent fogs, but high humidity accompanied by lack of rainfall, and relatively cool (summer below 24°).
(*p*) The same, with a higher temperature (summer above 28°).
(*p'*) The same, but with summer temperatures 24° to 28°.
(*s*) Dry season in summer of that hemisphere.
(*w*) Dry season in winter of that hemisphere.
(*s' w'*) The same, but rainy season delayed after autumn.
(*s'' w''*) The same, but rainy season overlapping with small dry season introduced.
(*u*) Sudan temperature course, coldest month after turn of the sun.
(*v*) Cape Verde course of temperature, warmest month in autumn.
(*x*) Transition type with early summer rain.
(*x'*) The same with infrequent but intense rain at all times of the year.

L. F. RICHARDSON ON WEATHER PREDICTION BY NUMERICAL PROCESS.

By EDGAR W. WOOLARD.

[Weather Bureau, Washington, D. C., March 15, 1922.]

Weather forecasting as conducted by the chief meteorological services of the world for many years past is completely empirical. Yet it can not be doubted that the processes of weather are simply examples of the operation of ordinary physical laws, although special methods may be required for the treatment of the special problems involved. The ultimate object of all meteorological work is to lead up to an insight into the physical processes which effect changes in weather—all our forecasting is the anticipation of these changes. The method of forecasting by empirical rules and past experience is simply a stage in the classification of the physical processes; it leads, as we know, to excellent results in the hands of the experienced, but its capacity is limited, and the limit is very soon reached. To carry it further, or to make out the true inwardness of its application in special cases, we must depend upon our knowledge of the dynamics and physics of the atmosphere.

In the present position of meteorological science, there are two extremes of opinion, both of which ought to be, and undoubtedly are by most meteorologists, avoided: Either to think the penetration into the secrets of the subject to be so difficult that we must be content to forego the attempt and deal with what we have; or to think it so easy that only observations are required, and the training of our brains of no account. As a matter of fact, brains without observations are certainly of no avail at all in any problem dealing with Nature; and observations, however numerous and widely distributed, will not exonerate us from the use of highly trained intelligence.[1]

Meteorology becomes exact only to the extent that it develops into a physics of the atmosphere. The ancients had a not inconsiderable knowledge of both meteorological facts and certain branches of physics, but no one dared to combine this knowledge in order to explain, for example, the monsoon winds. The growth of meteorological and of physical knowledge during and after the Renaissance prepared the way for some investigating spirit to perceive, sooner or later, the relationship between meteorological phenomena and physical laws; this relationship between the two sciences first came to be recognized, and the first step taken toward the development of a physics of the atmosphere, in the work of Halley and of Hadley, just following the great revolution in astronomy. However, by one stroke astronomy became an exact science, while meteorology took only a step in that direction. The transformation of meteorology into an exact science necessarily, from the transcendent complexity of the problems involved, called, and still calls, for extensive further development of both theoretical physics and observational meteorology.

Parallel with the subsequent steady progress of experimental and theoretical physics and of pure mathematics, was a growth of knowledge of climatology and descriptive meteorology. The combination of meteorological and physical facts has resulted in many excellent studies of theoretical meteorology, particularly since the time of Ferrel's pioneer work on the mechanics of the earth's atmosphere. Such studies are of the utmost importance to the practical problem of forecasting, since they help toward a better understanding of the phenomena of the atmosphere. Furthermore, in addition to having their scientific importance and interest, they bring us nearer the ultimate goal of the possibility of making forecasting a science instead of an art. With complete observations available from an extensive portion of the free air, the problem is to apply the equations of mathematical physics to the actually existing atmospheric conditions, and to compute the conditions that will follow. An objection usually urged against this idea is, "How can this be of any use? The calculations must require a preposterously long time. Under the most favorable conditions it will take the learned gentlemen perhaps three months to calculate the weather that Nature will bring about in three hours. What satisfaction is there in being able to calculate to-morrow's weather if it takes us a year to do it?" However, in the words of Bjerknes,[2] "If only the calculation shall agree with the facts, the scientific victory will be won. Meteorology would then have become an exact science, a true physics of the atmosphere. When that point is reached, *then* the practical results will soon develop. It may require years to bore a tunnel through a mountain. Many a laborer may not live to see the cut finished. Nevertheless this will not prevent later comers from riding through the tunnel at express-train speed."

Contemporary research in this field is being carried on largely by V. Bjerknes, of Norway, and L. F. Richardson, of England. It is to the latter that we owe the remarkable work now before us, *Weather Prediction by Numerical Process.*[3] Previous investigations have considered but one or two phases of the general problem—usually the purely dynamical—and have frequently been limited to more or less idealized conditions. Mr. Richardson, however, has dared to begin the discussion of the motions and phenomena of the *actual* atmosphere under the combined influences of *all* the principal factors, including radiation and absorption, evaporation and condensation, eddy motions or turbulence in the lower atmosphere, etc., gathered into one set of systematic mathematical equations, and to attempt to utilize this

[1] *Cf.* Sir Napier Shaw, "The Outlook of Meteorological Science," MO. WEATHER REV., 48, 34, 1920; *Quar. Jour. Roy. Met. Soc.*, 45, 95, 1919.

[2] V. Bjerknes, "Meteorology as an Exact Science," MO. WEATHER REV., 42, 14, 1914.

[3] Lewis F. Richardson. *Weather Prediction by Numerical Process*, Cambridge Press 1922. 4to, xii, 236 pp. The manuscript was completed in 1916, but was revised, and a numerical example worked out, in France during intervals of transporting wounded, 1916-1918. Upon being sent to the rear in 1917 the working copy was lost, to be rediscovered some months later under a heap of coal. It was again revised in 1921.

scheme in computing future conditions—an undertaking which is the first step toward fulfilling a hope and desire expressed by the late Cleveland Abbe.[4]

To quote from the *Preface:*

The process of forecasting, which has been carried on in London for many years, may be typified by one of its latest developments, namely, Col. E. Gold's *Index of Weather Maps*. It would be difficult to imagine anything more immediately practical. The observing stations telegraph the elements of the present weather. At the head office these particulars are set in their places upon a large-scale map. The index then enables the forecaster to find a number of previous maps which resemble the present one. The forecast is based on the supposition that what the atmosphere did then it will do again now. There is no troublesome calculation, with its possibilities of theoretical or arithmetical error. The past history of the atmosphere is used, so to speak, as a full-scale working model of its present self.

But—one may reflect—the *Nautical Almanac*, that marvel of accurate forecasting, is not based on the principle that astronomical history repeats itself in the aggregate. It would be safe to say that a particular disposition of stars, planets, and satellites never occurs twice. Why then should we expect a present weather map to be exactly represented in a catalogue of past weather? Obviously the approximate repetition does not hold good for many days at a time, for at present three days ahead is about the limit for forecasts in the British Isles. This alone is sufficient reason for presenting, in this book, a scheme of weather prediction, which resembles the process by which the *Nautical Almanac* is produced, in so far as it is founded upon the differential equations, and not upon the partial recurrence of phenomena in their ensemble.

The scheme is complicated because the atmosphere is complicated. But it has been reduced to a set of computing forms. These are ready to assist anyone who wishes to make partial experimental forecasts from such incomplete observational data as are now available. In such a way it is thought that our knowledge of meteorology might be tested and widened, and concurrently the set of forms might be revised and simplified. Perhaps some day in the dim future it will be possible to advance the computations faster than the weather advances and at a cost less than the saving to mankind due to the information gained. But that is a dream.

The state of the atmosphere at any point is specified by the values of seven dependent variables—the velocity horizontally toward the east, horizontally toward the north, and vertically upwards; density; joint mass of solid, liquid, and gaseous water per mass of atmosphere; temperature; and pressure. There are four independent variables—time, height above mean sea level, longitude, and latitude. Atmospheric phenomena are then completely described by seven fundamental differential equations; among these, temperature is eliminated, and the vertical velocity solved for, leaving five main equations to give the time rates of change of the remaining variables. The upper layers of the soil and sea are also taken into account.

In order to obtain a practical solution of these equations, recourse is had to the powerful Calculus of Finite Differences, using the method of Central Differences. The surface of the earth is divided into quadrilaterals by parallels and meridians, the author reaching the tentative conclusion that the parallels should be separated by 200 kilometers, and the meridians spaced uniformly at the rate of 128 to the whole equator, alternate meridians being omitted in high latitudes; the atmosphere is divided into five conventional strata at fixed heights of 2, 4.2, 7.2, and 11.8 kilometers above sea level. The fundamental equations are integrated with respect to height across these strata; special treatment has to be accorded the upper stratum. The centers of the squares are supposed to be the points for observing and recording the meteorological elements at the surface and aloft. If we imagine the squares to be colored alternately red and white like a chessboard, then those of one color should contain the pressure, temperature, and humidity, the others the density and wind velocities. To carry out the numerical solution of the equations, a piece of paper is ruled in squares corresponding to the squares on the earth's surface, and inside these squares are written the values of the dependent variables at the center. The infinitesimal differentiating operators in the equations are then replaced by the finite difference operators, and arithmetic is used instead of symbols, the increments being computed from the above tabulation; the time increment is taken as six hours. The increments of the variables with respect to time may then be computed; at the end of the process, the errors due to the finiteness of the differences may be estimated. In order to convince the reader of the reliability of this method, and to exhibit its powers and limitations, it is first applied to a simple example which is also solved analytically.

Thus we see the scheme consists of tabulating initial data of observation at certain latitudes, longitudes, and heights arranged in a pattern which, by borrowing a term from crystallography, may be called a "space-lattice," so as to give a general account of the state of the atmosphere at any instant over an extended region up to a height of, say, 20 kilometers, small scale phenomena being smoothed out; difficulties connected with lack of data over uninhabited regions, etc., may be partially overcome through the use of "normal" values at the boundaries. Then by operating upon the the tabulated numbers we obtain a new table representing approximately the subsequent state of the atmosphere after a brief interval of time; wherever in the lattice a pressure, say, is given initially, there the numerical process yields a pressure, so that we have a "lattice-reproducing process." The process can then be repeated so as to yield the state of the atmosphere after twice or thrice the same interval, and so on, but the errors accumulate of course, and besides each successive table is smaller than its predecessor, having lost a strip around the edge.

The method is applied to a very complete set of observations over middle Europe at 1910 May 20d. 7h. G. M. T., for which Bjerknes has published detailed charts. The resulting forecast is quite satisfactory, considering the amount and distribution of initial data: For of all the reasons that have determined the present distribution of meteorological stations, the nature of the atmosphere as summarized in its chief differential equations, is not one; and in the present case, errors seem to have been present in the initial wind data, also.

This book is an admirable study of an eminently important problem; being a first attempt in this extraordinarily difficult and complex field, it necessarily possesses, self-confessedly, many imperfections; and is by no means, of course, the final word; however, it indicates a line of attack on the problem, and invites further study with a view to improvement and extension. There are listed a number of problems still awaiting investigation. Perhaps the most serious handicap to studies in this field is the lack of adequate observational material. So far as the purely mathematical difficulties which the complexity of the subject introduces are concerned, they are surmountable. For the Philosophy of Mathematics teaches us that[5] the power of pure mathematics is unlimited—its development can not be stayed—it meets difficulties by a creative act which leaps over them; whence the nature of the peculiar rôle it plays in the physical sciences.[6] It is sincerely to be hoped that the author will continue his excellent work along these lines, and that

[4] Cleveland Abbe, "The Weather Map on the Polar Projection," MO. WEATHER REV. 42, 36, 1914.

[5] See, e. g., J. B. Shaw, *Lectures on the Philosophy of Mathematics*, Chicago, 1918.

[6] R. D. Carmichael, "The Provision made by Mathematics for the Needs of Science," *Science* (N. S.), 45, 465, 1917.

other investigators will be attracted to the field which he has opened up. The results can not fail to be of direct practical importance as well as of immense scientific value.

At the end of the book is a full explanatory list of notation in English and Ido. The mechanical execution of the work conforms to the usual high standard of the Cambridge University Press.

METEOROLOGY ON CAPTAIN AMUNDSEN'S PRESENT ARCTIC EXPEDITION.

By H. U. SVERDRUP, in charge of the scientific work.

Captain Amundsen's expedition left Norway in July, 1918. The plan was to follow the coast of Siberia eastward to the vicinity of Bering Strait, thence proceed to the north and let the vessel, the *Maud*, especially built for this expedition, freeze in. The vessel was then to be carried with the drifting ice fields across the Arctic Sea until it was released from the grip of the ice between Spitzbergen and Greenland, where the ice masses from the Arctic are slowly drifting south to the Atlantic Ocean. The main object of the expedition was to study the physical conditions of the Arctic Sea by determining depths, temperatures, salinities, and currents. But along with the oceanographical work, a number of other observations, mostly of geophysical interest, were to be carried out, as, for instance, meteorological observations which were to be extended to the upper air by means of pilot balloons and kites, observations of solar and nocturnal radiation, of the temperature distribution in the ice, and magnetic observations in cooperation with the Department of Terrestrial Magnetism of the Carnegie Institution of Washington. However, the ice conditions forced the expedition to winter three times in different places on the coast of Siberia, and in the summer of 1921, the *Maud* had to be sailed to Seattle for repairs.

The first wintering took place close to Cape Chelyuskin, the north point of the Continent. During the sea voyage, the pressure of the air had been registered continuously, and temperature, wind, and cloudiness had been noted six times a day. Shortly after the *Maud* was frozen fast in the vicinity of Cape Chelyuskin, a meteorological hut, containing thermograph, hygrograph, thermometers, and hygrometer was placed on the ice at a distance of about 50 meters from the vessel, and an anemograph was placed on board on the main boom, with the cups 3.5 meters above the roof of the deck's hut.

The meteorological registration for this winter showed several characteristic features. Especially were the frequent storms in the months October to January of interest, because barometric pressure, wind, and temperature always changed in a similar way during the development of the storm. Falling barometer was accompanied by a southwest gale, which might reach a velocity of 50 miles per hour, and by rising temperature, but at the moment the barometer stopped falling, the wind changed abruptly to northeast, and the temperature dropped as much as 20° C. in a few hours. This change of the meteorological elements when a storm passes is similar to the one experienced here when a cold wave passes a place, but the wind directions are here different. The wind directions noted by us indicate that the progression of the cold waves in high latitudes takes place from northeast to southwest, at right angles to the direction of progress in this latitude.

As soon as the daylight returned after the dark season, every opportunity was used for sending up pilot balloons and kites. However, the wind conditions were generally not favorable for kite flights, so the results were not in proportion to the time devoted to the work, but the few successful flights showed clearly the great temperature inversion which, in the winter, is found in the lower strata of the atmosphere in the Arctic. Attempts to send up captive balloons on calm days failed, partly because the rubber balloons to be used for this purpose were too old, having been procured in 1913, partly because we had no means to overcome the difficulties arising from the low temperatures. In May and June, the work with pilot balloons and kites had to be abandoned, because the time had to be devoted to a survey of the most northerly peninsula of the Continent.

The ice held us bound for a whole year, less one day, at Cape Chelyuskin. When we left Captain Amundsen hoped to succeed in beginning the drift. He wanted, however, to send the scientific observations home, to prevent their loss in case the vessel was crushed by the ice. They were, therefore, entrusted to two men, who were to bring them to the nearest settlement, the Russian wireless station at Dickson Island, about 600 miles to the southwest. Along the coast, which they were to follow, three caches with provisions had been left by former expeditions. The plan seemed safe, but unexpected events happened. Captain Amundsen did not succeed in beginning the drift, and the *Maud* reached Nome safely in July, 1920, but the two men who carried our observations lost their lives. With them all the meteorological registrations, together with registrations of the magnetic declination and the tides, were lost, but copies of the meteorological observations made three times daily, at 8 a. m., 2 p. m., and 8 p. m., L. M. T., and of the results of pilot-balloon ascents and kite flights, had fortunately been made and kept on board the vessel.

In September, 1919, when the *Maud* proceeded to the east, the ice conditions were still more unfavorable than in the summer of 1918. Every attempt to penetrate to the north was frustrated, and at the end of the month there was nothing left but to seek a new place for winter quarters on the coast. Thus it happened that the *Maud*, in the winter of 1919–20, was frozen in about 700 miles west of Bering Strait at the island of Ayon. When we stopped there, the island was inhabited by natives of the Siberian tribe known as the Chukchi, who, in a short time, would leave the coast and follow their herds of domesticated reindeer to the inland, where they were accustomed to spend the winter. Captain Amundsen realized that here we had a unique opportunity to study the habits and customs of this little-known tribe, and therefore suggested that I join the natives, accompany them to the interior and return to the ship in the spring. I left the *Maud* in the beginning of October, 1919, and found her in the same place when I returned in May, 1920, after having spent seven and one-half months alone among the Chukchi. Besides having gathered information and made collections of ethnological interest, I had taken meteorological observations usually three times a day, and had secured magnetic observations from five stations in an inaccessible part of the country. On board the *Maud* the registrations of the meteorological elements had been kept up continuously, and the daily observations taken regularly.

In July, 1920, the *Maud* was released from the ice, and Captain Amundsen proceeded to Nome where he had decided to call in order to take on board additional equipment for the drift. After a short stay in Nome, the ex-

pedition left on August 8 with the intention, if possible, of penetrating to the north and beginning the drift. But now the ice hardly permitted us to get inside the Bering Strait. Eighty miles from the strait, at Cape Serdze Kamen, the *Maud* was closed in and had to winter for the third time. During this winter the meteorological registrations and observations were kept up to the same extent as during the preceding winter.

A comparison, particularly between the development of a storm in the vicinity of Bering Strait and at Cape Chelyuskin, discloses several interesting facts. At Bering Strait, falling barometer in the winter is accompanied by southeast wind and rising temperature, but rising barometer is accompanied by northwest wind and falling temperature. This change of the meteorological elements corresponds to the one experienced here when a cold wave passes a place, which indicates that the direction of progress of the cold waves at Bering Strait is approximately the same as here, namely, from northwest to southeast, and not as at Cape Chelyuskin, from northeast to southwest.

Along the coast of the Chukotsk Peninsula, the weather has an extremely local character due to the topographic features of the land. The weather may be fair, with only a light wind along part of the coast, but, for example, in a valley running parallel to the general wind direction, a blizzard may be raging. The wind blows as from a funnel, whirling the snow up and even carrying pebbles and small stones along. At the border of such a local blizzard we once had opportunity to observe some very interesting eddies with vertical axes similar to small tornadoes, which were made visible by the drifting snow. We saw whirling cylinders of snow with a diameter from 2 to 12 meters and a height of about 8 meters. These cylinders, which rotated counterclockwise, moved comparatively slowly in the direction of the wind. These eddies must be quite common under the conditions mentioned, because the natives use a particular name for them. They probably are common at the border of any local air current, but they are not frequently made visible by drifting snow.

The following may illustrate the frequency of storms at the coast. From February to April, 1921, two of us traveled with dog sledges along the coast in order to take magnetic and meteorological observations and gather information of ethnologic interest. We covered about 1,200 miles in 69 days, but on 23 of these we could not proceed on account of blizzards, even though we traveled several times on days when the natives refused to leave the tents. The short distance to the open water in Bering Sea is certainly responsible for the unsettled character of the weather at this coast.

In May and June a number of pilot balloons were sent up. The new balloons we had received in Nome in 1920 through the courteous assistance of the United States Weather Bureau proved to be very satisfactory, so that altitudes between 10 and 15 kilometers were frequently reached.

All the meteorological registrations and observations from the three years, 1918 to 1921, have been forwarded to the Norwegian Meteorological Institution in Christiana, where they will be reduced and published. At present no copy of the observations is available to me, so I have to confine myself to this brief summary regarding the observations made.

Captain Amundsen's expedition is starting out again from Seattle at the beginning of June next. His plans are unchanged; he intends to go from Bering Strait to the north and drift with the ice fields across the Arctic Sea. During the drift barometric pressure, temperature, humidity, and wind are to be registered continuously, and the registrations to be checked by three daily observations. We may also observe the temperature at the top of the mainmast, 30 meters above the deck, by means of a resistance thermometer. For investigation of the upper air currents we have 1,000 pilot balloons, for which the hydrogen has to be developed on board by means of CaH_2 and water. Whether we shall be able to get any results from the pilot balloons during the dark season or not is doubtful. We have a supply of small transparent paper lanterns with candles to be attached to the balloons, but the range of visibility for these lanterns may be too small to give satisfactory results. Furthermore, the expedition has a kite reel and 18 kites, four of which, through the courtesy of the United States Weather Bureau lent the expedition to replace some which were damaged at Cape Chelyuskin. The characteristics of the wind over the Arctic Sea, particularly the change of the wind with altitude, are too little known to permit any opinion as to the successful use of kites. These winds may, however, be more favorable than they are close to the coast. The expedition is also to carry airplanes to be used for geographical exploration, starting from and returning to the ship. During these flights meteorological observations may be carried out.

The most important addition to the equipment of the expedition is a wireless transmitter which will make it possible for us to send daily weather reports. We hope to be able to communicate with Nome during the first part of the drift, and with Spitzbergen during the last part. Whether the daily weather reports from the central Arctic regions will be of value for the weather forecasts in the Temperate Zone is an open question, but they will certainly be of great meteorological interest.

INSTRUCTION IN METEOROLOGY FOR AVIATORS.

By WILLIS RAY GREGG, Meteorologist.

[Weather Bureau, Washington, D. C., March 6, 1922.]

The Weather Bureau was recently requested by the United States Air Service to furnish a course of lectures on meteorology to pilots at certain aviation fields in California. The first step in planning such a course is to prepare a suitable outline or to adopt one already in existence. In this case, none of those heretofore used seemed quite satisfactory, since these earlier ones were designed for more extended and complete courses than here contemplated. The chief requirements of a course for aviators under present conditions are that the lectures should be few in number, should be brief and to the point, should be illustrated copiously with lantern slides and, while containing enough information on *general* meteorology to make possible a logical development of the entire subject, should be *mainly* devoted to those features which are of most concern in actual flying. To meet these requirements the suggested outline or syllabus, given at the end of this note, was prepared, and suitable lantern slides were furnished. It is believed that a course of this kind should have not less than ten lectures, but, if that many can not be arranged for, some of those given in the outline can be consolidated. On the other hand, several of the lectures can be subdivided, in case arrangements can be made for a more extended course. In all cases the subject of the tenth lecture would be changed to suit the region in which the pilots would do most of their flying.

SUGGESTED OUTLINE OF COURSE OF LECTURES FOR AVIATORS.

I. General meteorology.
- A discussion of the planetary distribution of surface pressure, temperature, moisture, cloudiness, precipitation, and wind. Climatic zones, their extent and their interrelations.

II. Instruments and methods of observation.
- (*a*) At the surface (all instruments used).
- (*b*) In the upper levels:
  - Kites and meteorographs.
  - Pilot balloons and theodolites.

III. Physical properties of the atmosphere.
- (*a*) Constituents and their relative importance (the atmosphere is a mixture).
- (*b*) Vertical structure—troposphere and stratosphere—characteristics of each. (Troposphere a region of decreasing temperature and considerable cloudiness; stratosphere, of little change in temperature and no cloudiness. Boundary plane between the two about 17 kilometers in Tropics; about 12 at latitude 45° and about 11 at latitude 50°.)
- (*c*) Decrease of pressure with altitude. Hypsometry (half of earth's atmosphere is within $5\frac{1}{2}$ kilometers, or $3\frac{1}{2}$ miles, of surface).
- (*d*) Change of temperature with altitude, normally a decrease in troposphere, but inversions are frequent in winter and during clear nights, particularly in the interior of the country.
- (*e*) Change of humidity with altitude. Absolute humidity normally decreases owing to lower temperatures in upper levels. Relative humidity on the average also decreases somewhat, but varies greatly according to conditions of cloudiness.

IV. Winds.
- (*a*) Direction.
  - Gradient versus actual.
  - Change with altitude—normally turn clockwise, except winds from north to east, which turn counterclockwise. Large percentage of west component in upper levels.
- (*b*) Velocity.
  - Gradient versus actual.
  - Change with altitude, normally an increase of about 100 per cent in first half kilometer, more gradual increase at higher levels, but there is much variation.
  - Change with seasons, much higher in winter than in summer, owing to steeper poleward temperature gradient.
  - Change with direction, much higher with west than with east winds.

V. Thunderstorms.
- (*a*) Processes of formation.
- (*b*) Frequency, seasonal, diurnal and geographic.

VI. Fogs and clouds.
- (*a*) Fogs, processes of formation; frequency, seasonal, diurnal and geographic.
- (*b*) Clouds, processes of formation; types and approximate mean and limiting altitudes; frequency, seasonal, diurnal, and geographic.

VII. Cyclones and anticyclones.
- Characteristics of each; distribution of pressure, temperature, cloudiness, wind and precipitation; frequency, seasonal and geographic; direction and rate of travel, "storm paths."

VIII. Forecasting.
- (*a*) Assembling the data.
- (*b*) Forecasts made:
  - Surface weather.
  - Surface temperature.
  - Surface winds.
  - Upper air winds.

IX. Meteorology and aviation.
- (*a*) Review of preceding lectures, particularly IV to VII, with special reference to their application to aviation, stressing:
  1. Importance of knowing the winds along a flying route, thus enabling an aviator to know at what altitude he can make most progress.
  2. Importance of knowing weather conditions along a route, especially the existence of thunderstorms, fogs, precipitation, etc.
- (*b*) Gustiness: its causes,—local heating more pronounced over a black soil than over a light one; over a plowed field than over a pasture, etc., thus giving rise to vigorous convection—a dangerous condition; buildings and topographic irregularities produce eddies and gusts, their influence extending to a considerable height, on the average about four times that of the height of the obstruction itself above the general level of the earth's surface in its vicinity; gustiness especially vigorous near cumuli; flying close to them should be avoided.

X. California weather and climate and their relation to aviation.

THE GREAT GLAZE STORM OF FEBRUARY 21-23, 1922, IN THE UPPER LAKE REGION.

DISCUSSION OF GENERAL CONDITIONS.

By A. J. HENRY.

[Weather Bureau, Washington, D. C., Mar. 27, 1922.]

An intense glaze storm occurred on February 21–23 in portions of the upper Mississippi Valley and in the States of Wisconsin and Michigan, in which a very large amount of damage was done to overhead telegraph, telephone, and other electrical transmission lines in the regions mentioned. A more serious loss, in an æsthetic sense, was sustained by shade and ornamental trees and orchards in the States named, a loss which can not be replaced within the lifetime of the present generation.

The present winter has been rather exceptional in that 4, possibly 5, severe glaze storms have occurred in rather widely separated parts of the country.[1] These storms appear to have had one common point in their origin, viz, that of a cold surface air current being overrun by a warmer current. The latter being thus elevated and its moisture condensed, as rain which, falling upon objects having a temperature some degrees below 32° F., is frozen as it reaches them. The Michigan-Wisconsin storm was exceptional in its duration and the amount of precipitation in the form of rain which occurred; it was also exceptional in the fact that it occurred in very nearly the geographical center of the continent, farther north than is usual for such storms in February.

ANTECEDENT WEATHER CONDITIONS.

Pressure distribution February 20.—An anticyclone of considerable magnitude whose longer axis extended from Chicago, Ill., to Bismarck, N. Dak., was moving rather rapidly eastward. Surface winds over Iowa, Missouri, eastern Nebraska, and eastern Kansas, were from the northeast due to the position of the anticyclone. A cyclonic area of wide geographic extent with its center over Nevada dominated the winds west of the Rockies.

Free-air winds on 20th.—Free-air observations by means of kites and pilot balloons were made at so few places that the picture afforded by them is incomplete. A kite flight at Drexel, Nebr., gave surface winds from the northeast, shifting to south at 1,104 meters above the surface, southwest at 1,604 meters west-southwest at 2,104 meters and to west at 2,604 meters continuing from that direction up to the top of the flight at 3,910 meters where the velocity was 23.6 meters per second. Pilot balloon flights on the afternoon of the same date show southwest or south-southwest winds at the 1,500 meter level at Dayton, Ohio, and also at Broken Arrow, Okla. Thus it would seem that as a result of the interaction of the anticyclonic and cyclonic systems above mentioned, southwest winds were merging with a strong westerly current at and above 4 kilometers.

[1] MO. WEATHER REV., November, 1921, 49: 612; December, p. 661.

Pressure distribution, February 21.—The anticyclone above mentioned continued its eastward movement preserving its conformation unchanged; the longer axis now extended from Albany, N. Y., to Sault Ste. Marie, Mich., and a second strong anticyclone appeared in the Canadian Northwest so that an unbroken area of high pressure and associated low temperature extended from eastern New York to Alberta, while the western cyclone still occupied the region from the Rockies to the Pacific but its influence now extends over the Plains States and into the upper Mississippi Valley. The surface winds over Iowa, Missouri, eastern part of Nebraska and Kansas, which on the previous day had been northeasterly are now southeasterly and rain or snow has set in over southern Iowa and northwestern Illinois. The temperature contrast between Iowa and upper Michigan is sharp, viz, from 30° in the former to zero in northern Michigan.

Efforts to penetrate the very extensive cloud blanket which shrouded this region were generally unsuccessful. At Drexel, Nebr., the kites collapsed at 816 meters above the surface in a south wind. At Ellendale, N. Dak., the wind was southeast at 556 meters and thence to the top of the flight which ended at 768 meters in conditions of extreme severity approaching that of a "blizzard." At Royal Center, Ind., farther south, surface winds were southeast becoming south at 775 meters above the surface; southwest at 1,775 meters, west-southwest at 2,275 meters, and continuing in that direction to the top of the flight which ended at 3,303 meters where the kites collapsed in the rain which had continued throughout the flight.

The southwest wind noted on the previous day at Drexel, Nebr., thus appears at about the same level at Royal Center, about 600 miles east of the first named, and here too it merged into a west wind at higher levels. To the east and south of the cloud-covered area pilot balloon flights show southerly winds generally as far south as the Gulf of Mexico, but not at levels above 1,500 meters, except as far west as Denver, Colo. The point we wish to emphasize is that doubtless there was a warm southerly current above the colder easterly current throughout the region where intense glaze prevailed.[2] As the center of the western cyclone approached the Mississippi Valley the surface temperature rose and accordingly the area exposed to the conditions which produced intense glaze is found farther to the northward than on the preceding day. This is shown graphically in figure 1.

[2] Cf. Meisinger, C. Le Roy: Precipitation of sleet and the formation of glaze in the eastern United States, Jan. 20-25, 1920, with remarks on forecasting. MO. WEATHER REV., February, 1920, pp. 73-80.

IN WISCONSIN.

By J. E. LOCKWOOD, Meteorologist.

[Weather Bureau, Milwaukee, Wis., March 16, 1922.]

This sleet and glaze storm will go down in the climatological history of Wisconsin as the most remarkable, most spectacular, and most destructive storm of the kind that has visited the State since the taking of systematic weather observations was begun.

In the northern half of the State the precipitation was in the form of snow and, added to the amount already on the ground, made depths of 20 to 50 inches on the level and drifted to great heights. In the southern half of the State it fell as rain, but most of the time during that period surface temperatures were below freezing, and the rain froze after it had fallen on trees, wires, and other surfaces, the ice accumulating to such thickness as to bear down, with its unusual weight, electric wires and poles and great branches of trees.

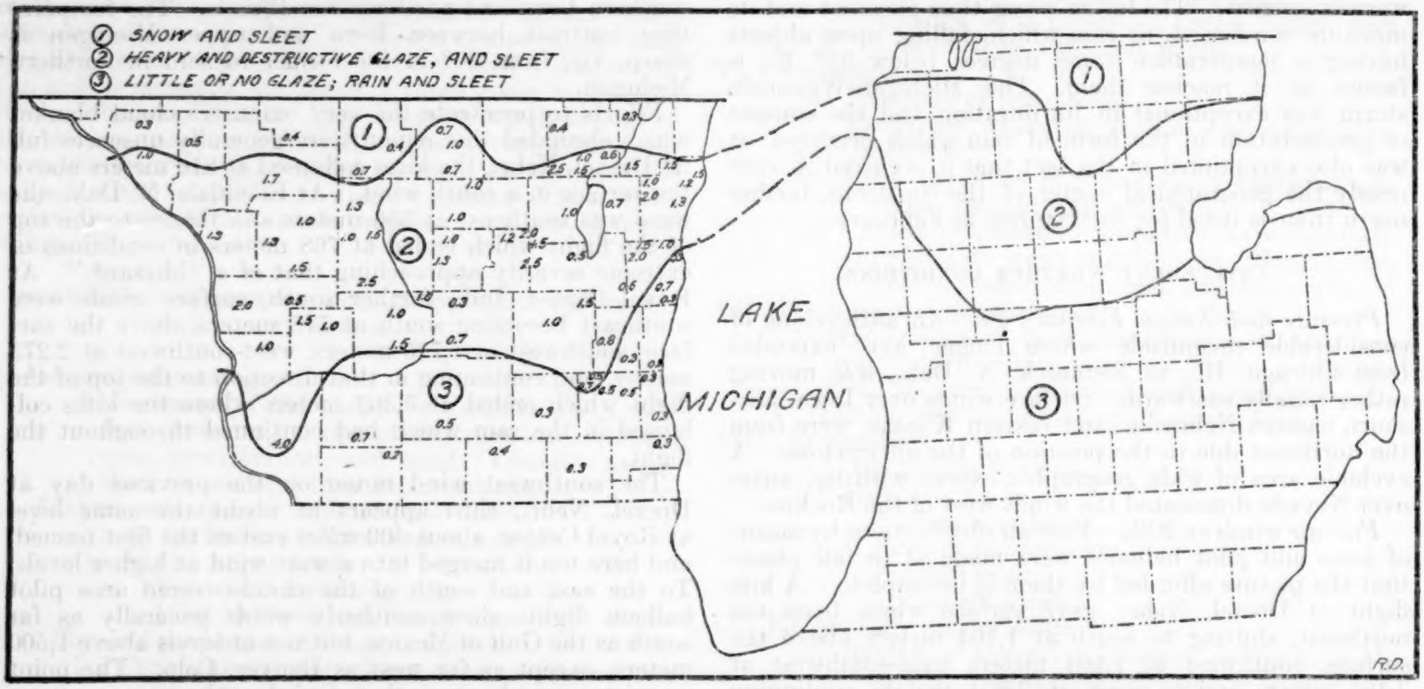

FIG. 1.—Portions of Wisconsin and Michigan in which glaze was formed, and in which the precipitation fell as rain and snow.

By noon of the 22d, the ice burden had become so heavy that wires were beginning to pull and break. By night, practically every circuit was broken in many towns in the heavily glazed area. Trees and poles continued to fall all through the night and during the 23d, and streets were badly littered and blocked to traffic in many places. Wires were a tangle and there was danger of electrocutions.

SLEET.

Along the border line between the areas of rain and snow, respectively, the rain drops froze before reaching the ground, forming sleet which accumulated to unusual depths. It was described by some of our cooperative observers as quoted below:

Mr. Carl Stange, Neillsville: "The sleet was like coarse rock salt." Mr. W. H. Scott, Stanley: "Much of the precipitation came in the form of small hailstones. It was just like a bed of shot to walk in." Mr. C. G. Stratton, River Falls: "The precipitation was mostly frozen rain; the ice fall was perfectly dry and made progress difficult. Each step splashed the pellets away, after which they closed in again. They were one-sixteenth to one-tenth of an inch in diameter. On sidewalks and in roadways and other depressions, the pellets accumulated as deep as 10 to 12 inches. The average depth was around 2 inches. When melted it made 1.10 inches of water." Mr. E. F. Stoddard, Downing: "The ice granules that fell on the night of the 21st, to a depth of 6 inches, practically stopped all traffic."

WHERE THE HEAVIEST DAMAGE OCCURRED.

Figure 1 shows where the damage to telephone and telegraph lines, interurban trolley lines and electric power lines was very heavy. The figures show the diameter of the ice-covered wires. This varied from a few tenths of an inch to 2.5 inches or more, forming a rod of ice as thick as a man's wrist, in many places throughout the area. Added to that great weight, was the weight of icicles which formed along the wires, often very close together and varying in length from 3 to 12 inches.

Weight of the ice.—To form an estimate of the great weight the wires, poles, and trees were called upon to bear, the following may be cited:

At Oshkosh a small piece of ice-covered branch was found to weigh 2 pounds. Without the ice it was found to weigh 2 ounces, or one-sixteenth of its former weight. At Ripon a similar test was made, using a large branch, and it was found that the ice had increased the weight of the branch to twenty times its normal weight. One man reported that a 6-inch twig, weighed by him, tipped the scales at 2 pounds. At Wild Rose a section of wire, 1 foot long, was cut and its weight determined as $1\frac{1}{4}$ pounds, and at Camp Douglas 1 foot of telephone wire weighed 2 pounds.

FIG. 2.—Showing icicle fringe on telephone wires and fences. (Courtesy of *Milwaukee Journal.*)

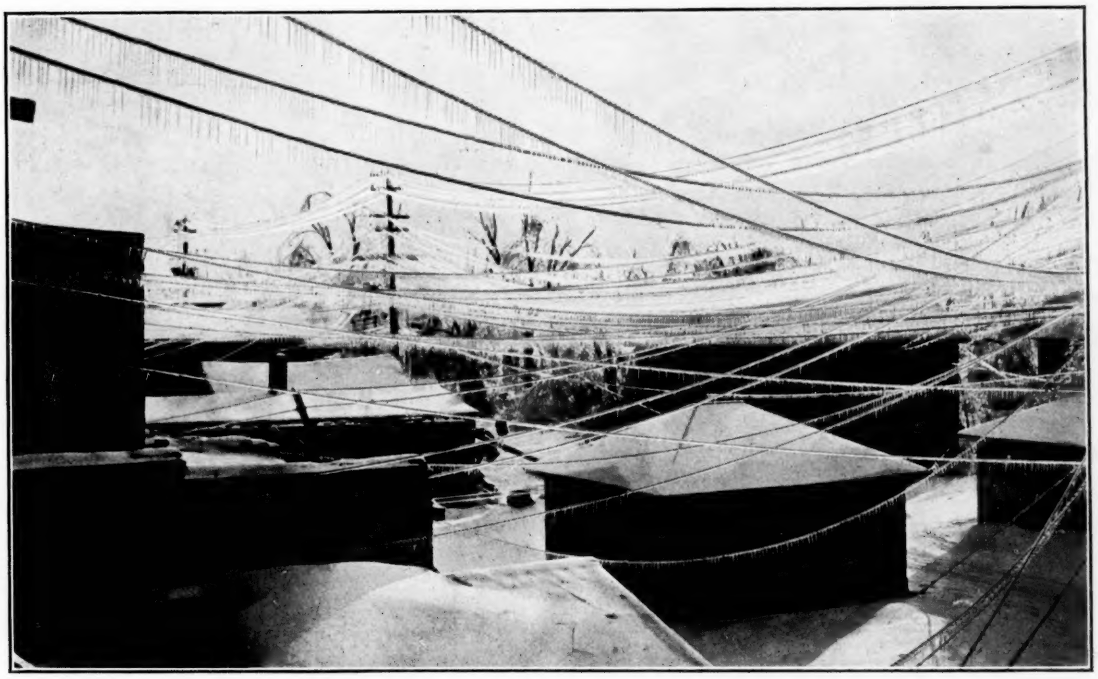

FIG. 3.—Ice cover and icicle formation at Tomah, Wis.

Mr. E. C. Thompson, observer in charge of the Weather Bureau office at La Crosse, is quoted as follows: "The ice-covered wires were as thick as your wrist. One lineman took ice from 3 feet of wire and it weighed 12 pounds. A man in Sparta weighed a small branch from a tree and then, knocking all the ice off, found that it weighed one-sixteenth of its original amount." (See Fig. 4.)

As telephone poles are usually spaced 130 feet apart and carry 40 wires, 1 pound of ice to the foot would put an additional weight on the poles of 5,200 pounds to the span. When a branch of a tree, overcome by from 10 to 16 times its usual weight, fell across these wires, they broke readily, and the poles, released of the balancing weight on one side, fell in the opposite direction, going down one after the other, like a row of dominoes. Often 2 or 3 miles of poles went down at one time. In one stretch of 6 or 7 miles every pole was down when the storm was over. At least 15,000, and more likely 20,000, poles were down when the storm was over, and telephone, telegraph, and light and power service was interrupted for from 2 to 15 days.

Where the poles held upright the wire stretched and sagged almost to the ground in many places. Most of the wire was rendered useless and will have to be discarded and new wire run in its place. The financial loss to telephone and telegraph companies was consequently very great, amounting in many instances to one-half of the investment.

Timber, fruit, and shade trees were severely damaged and a considerable percentage of them completely destroyed. Near La Crosse large fir trees were stripped of every limb and stood like tall masts. Shade trees lost large branches and many had to be cut down. Fruit trees were bent and broken by the weight of the ice or split through the middle by the branches bending to the ground in opposite directions. These latter were, of course, destroyed and they represented in a few places in the Fox River Valley as high as 40 per cent of the trees. In the Kickapoo Valley many apple orchards were badly damaged, but the percentage was not so high as in the Fox River Valley and was confined mostly to the ridges, while in the valleys the trees escaped severe damage.

Winter grains and grasses were injured by smothering, caused by the heavy coating of ice on fields and meadows.

THE CENTER OF DESTRUCTION.

The Fox River Valley and counties bordering on Lake Winnebago was the center of destruction, while in a belt 75 miles wide, extending westward to the Mississippi River, the damage was only slightly less severe.

Within this belt there are about 1,000,000 apple trees, but it is impossible to reliably estimate the financial loss caused by the damage to these orchards. The chief financial loss fell upon telephone, telegraph, and electric power companies. Independent farmers' telephone lines were hard hit and many of these companies lost nearly their entire outside equipment. Power plants lost many miles of poles and lines, and many manufacturing plants, depending upon them for power, were shut down for from two to five days. Cities depending upon them for light were without service for nearly a week.

COMMUNICATION CUT OFF.

Communication, except by wireless, with many cities within the heavily glazed area, was entirely cut off for 24 hours or more and all electric service seriously curtailed for from one to two weeks. Cities were in darkness by the night of the 22d, because of broken service wires, and all electric power had to be cut off to avert danger from live wires. The city of Oshkosh was without lights two nights and the fire-alarm system was out of order for two or three days. Neenah, Menasha, Appleton, and Fond du Lac were under similar conditions and the entire valley from Kaukauna to Fond du Lac was living in a primitive mode, as to light and transportation, for nearly a week.

TRANSPORTATION STOPPED.

Interurban electric lines were unable to give service for periods varying from two to three days to as many weeks. Between Little Chute and Appleton all trolley poles were down. The line from Oshkosh to Neenah was not in operation two weeks after the storm had passed.

Railroads suffered a very severe tie-up, the roads being blocked in the north by the great drifts and in the middle counties by heavy ice on the tracks. From Oshkosh nearly to Green Bay and in near-by counties the railroads had to resort to pick and shovel to remove solid ice from the tracks, a very laborious and time-consuming process. Most cities in all but the southern counties were without any train service whatever from one to two days, and at some places the blockade lasted a full week.

FLOODS.

Ice jams on rivers and the rapidly melting ice caused minor floods at Sheboygan, La Crosse, Darlington, Fond du Lac, and a suburb of Milwaukee. These caused considerable inconvenience but little monetary loss.

ESTIMATE OF THE LOSS.

From replies to inquiries sent to nearly 200 towns in the State an estimate of the loss to telephone, telegraph, and electric power companies by the prostration of their lines is placed at $8,000,000. A total loss of $10,000,000 in Wisconsin to all interests caused by this severe storm would be a conservative estimate.

THE WORK OF RESTORATION.

Two weeks after the storm had passed, the work of restoring electric circuits was still going on in the city of Oshkosh. Most of the electric service had been put in operation, but the street lights were not yet restored. Telephone service with other cities was complete but of a temporary character. The city of Fond du Lac was just recovering from the effects of the storm, which had been aggravated by a rise of the Fond du Lac River. This was caused by the rapidly melting ice, and streets were flooded over nearly three-fourths of the city.

It will be several months before telephone and telegraph lines are back to normal conditions.

CASUALTIES.

Fortunately, only two deaths resulted from the storm in this State. A fireman of Manitowoc was overcome by smoke while fighting a fire caused by crossed wires. A child was drowned when Keith Creek rose above its bank, near Beloit, Thursday the 23d.

Two engineers and two firemen were severely injured when the two engines, hauling a passenger train, were wrecked by heavy snow at Little Chute. In three other

derailments caused by the storm, trainmen were slightly injured.

EXCEPTIONALLY HEAVY RAINFALL.

The great destructiveness of this storm was the result of circumstances very favorable for the formation of glaze. One of the heaviest rainfalls ever known in this State, at this season of the year, fell slowly through a period of nearly 48 hours during which surface temperatures remained below freezing.

On trees the ice accumulation was almost entirely on the windward side. On the wires, the ice cover turned on the wires as the weight became unevenly distributed, and thus became nearly uniform in thickness until icicles began to form. This formation is shown very clearly in one of the accompanying photographs.

IN MICHIGAN.

By D. A. SEELEY, Meteorologist.

[Weather Bureau, Lansing, Mich., March 23, 1922.]

Probably the worst ice and sleet storm and one of the heaviest snowstorms on record in Michigan occurred February 21–23, 1922. Millions of dollars worth of property was destroyed. Railroad service was paralyzed and wire communication was cut off over a considerable portion of the northern half of the State for several days.

Reports received from the regular Weather Bureau stations, Wednesday morning, February 22, told of heavy snow in the northern portions of Wisconsin and Michigan with temperatures about 18° to 25°, and rain with thunder and lightning in southern Michigan, where the temperature was about freezing. Wires were down in the northern counties of the lower peninsula, due, as it was found later, to the fact that an exceedingly heavy coating of ice had accumulated on them and borne most of them to the ground.

At a number of stations in the north-central portion of the lower peninsula the amount of precipitation exceeded 4 inches. These stations were in the region where the precipitation was in the form of sleet or rain which froze as it fell and formed a solid sheet of ice. This ice coating was so thick and heavy that it broke off many branches of trees, even those of considerable diameter, and practically denuded all trees of smaller branches and twigs. In many orchards from 25 to 75 per cent of the older trees were broken off entirely. Younger orchards were injured somewhat less. Wood lots and shade trees were seriously damaged. Telegraph, telephone, and high-tension electric lines were borne to the ground and thousands of poles and supporting towers were broken off. For many miles along some of the railroads every pole was prostrated.

A number of reports were received giving definite weights of the coating of ice on twigs and wires. At East Tawas, Mich., a length of No. 14 telephone wire, 1 foot long, with its ice coating, weighed 11 pounds and the measurement was not made until a week after the storm had passed and undoubtedly considerable had melted and evaporated before it was weighed (see fig. 4). At Omer, Mich., the thickness of the ice coating was 4 inches. At Arcadia, a short twig weighing 1 ounce had an ice coating of 2 pounds. A larger twig about the size of a lead pencil supported a column of ice 9 inches in circumference. Several observers reported the ice coating to have weighed 20 to 40 times as much as the supporting branch or wire. The weight of ice on six high-tension electric cables between two supporting towers of the Consumers' Power Co. near Cadillac was computed by competent engineers to exceed $1\frac{1}{2}$ tons. (See fig. 7.)

The area included in the region of heaviest ice coating, as shown by figure 1, is bounded on the west and south by a line starting just north of Manistee, on the Lake Michigan shore, running southeastward through northeastern Mason and Newaygo Counties to southern Mecosta County, thence eastward through northwestern Saginaw County, and northeastward to Bay City. The northern boundary of the heavy damage extended from Frankfort, Mich., eastward across Benzie and Grand Traverse Counties, thence southeastward to southern Roscommon County and northeastward to the town of Oscoda on the Lake Huron shore. A few sections outside of this area also reported heavy damage, including the extreme northern portions of Otsego and Huron Counties.

As to the amount of damage done, the following statements might be made. In one orchard north of Manistee containing 45,000 trees, 50 per cent were reported as destroyed and will have to be cut away and replaced. In other smaller orchards a little farther north, from 50 to 70 per cent of the trees were destroyed. One of the larger telephone companies in the State, operating in the stricken region, reports an estimated loss of $400,000. A number of smaller companies were a complete wreck and in at least one case bankruptcy has followed and the line will not be rebuilt. A great many high-tension electric wires carried on steel towers were broken down and towers crumpled, one company alone losing 200 towers. The damage to wood lots, shade trees, etc., can not be estimated. A number of towns were left in total darkness for days after the storm. Train service was impossible not only on account of the ice coating on rails, but because all wires were down and it was impossible to issue orders over them. The roofs of many buildings collapsed under the heavy load of ice which weighed 16 to 20 pounds per cubic foot.

It seems probable that the total value of property destroyed and the damage to various industries due to the stopping of transportation, etc., will exceed $5,000,000.

A few quotations from reports received will give a better idea of the storm.

Benzonia, Mich.: "The damage is hard to calculate, but at least one-third of the growing timber is destroyed."—Wallace Nutting.

Morley, Mich.: "The storm was the most severe and destructive in Michigan during my stay here of 28 years. I had a forest of sugar maples, black cherry, beech, and elm, which I considered very valuable, and the destruction to it was almost complete."—W. F. Giddes.

East Tawas, Mich.: "The ice storm of February 21–22 last was the worst that has ever been experienced in this region."—R. G. Schreck, forest supervisor.

Hemlock, Mich.: "The sleet storm on February 22 did much damage to fruit trees, etc. I would estimate the damage in this township of $10,000."—A. C. Fehn, highway road commissioner.

Frankfort, Mich.: "A conservative estimate of damage to orchards in this township would be $5,000."—John C. McKinnon.

Lake City, Mich.: "Old orchards about 75 per cent ruined, shade trees badly damaged, young orchards damaged 5 to 20 per cent. I should judge that between $50,000 and $75,000 damage resulted in Lake City and vicinity."—Charles E. Taylor.

FIG. 5.—Effects of glaze on trees in Cadillac, Mich., Feb. 24, 1922.

FIG. 6.—Destructive effects on trees and wires in Cadillac, Mich., Feb. 22, 1922.

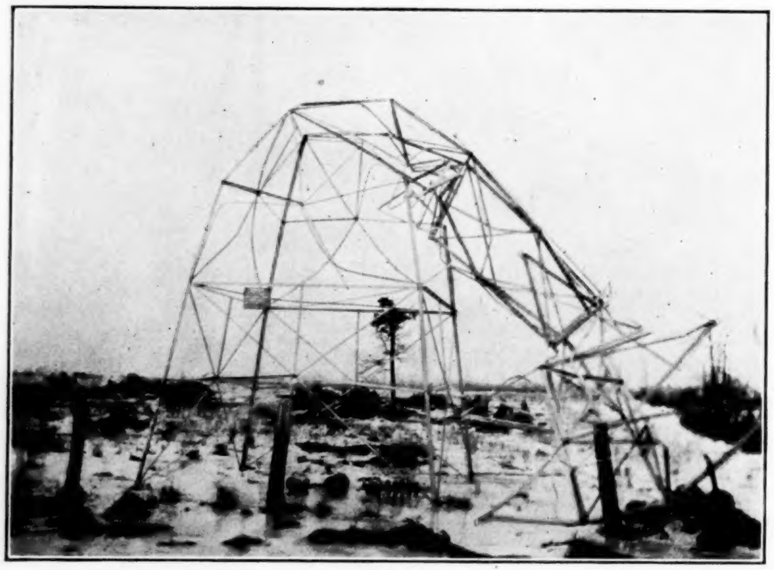

FIG. 7.—Transmission tower destroyed by glaze near Cadillac, Mich.

LeRoy, Mich.: "The estimation of money loss in this section is about $10,000. The trees had about 3 inches of ice on them."—Bennie Werner.

Reed City, Mich.: "Old orchards suffered the worst, 60 per cent of trees being ruined, and young orchards were about 25 per cent loss."—John Schmidt.

Bendon, Mich.: "The crust on the snow was solid enough to hold up a team, and continuing so for 11 days."—R. B. Reynolds.

Manton, Mich.: "Poplar trees were stripped, leaving the jagged central shaft; soft maples and elms were split to pieces. Hard maples had top branches all broken

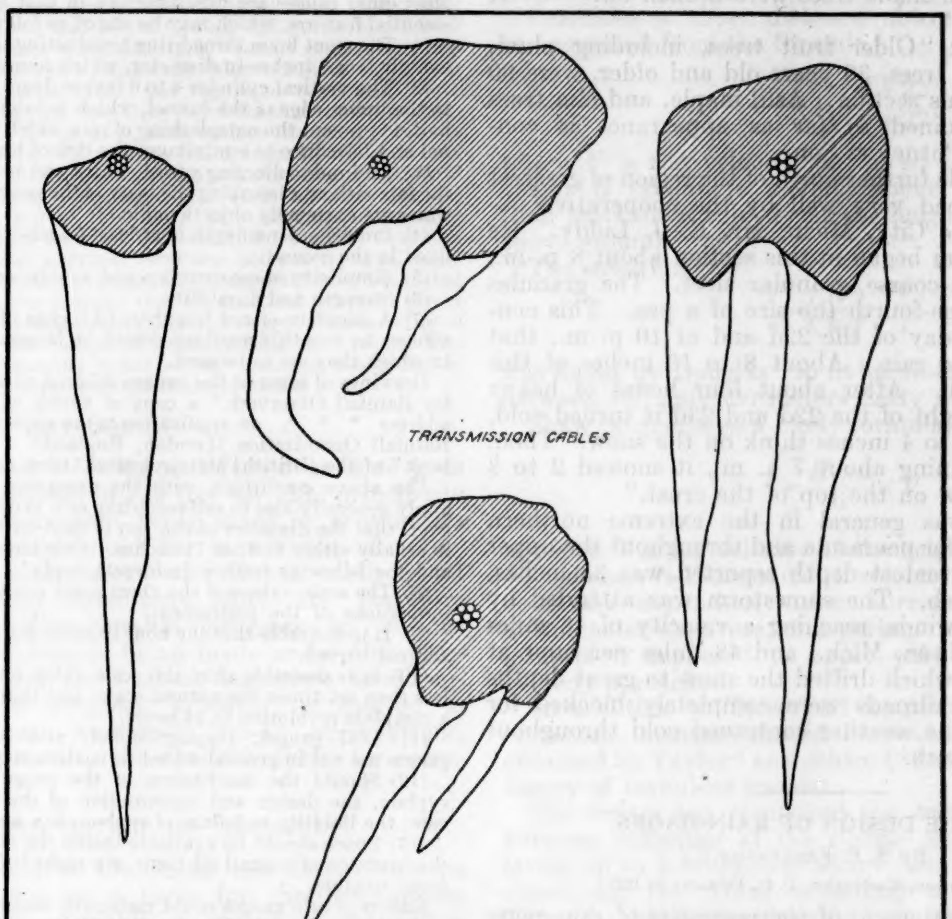

FIG. 4.—Specimens of icicles and ice coating removed from various kinds of wires near Cadillac, Mich. Some of these drawings were made a week after the storm. The icicles numbered 6 to 10 to the foot.

West Branch, Mich.: "The storm broke down about 10 per cent of the timber in Ogemaw State Forest. Nearly all old orchard trees were broken down."—Grover Zettle.

Luther, Mich.: "The damage to orchards, shade trees, and wood lots is appalling. I am looking for a 50 per cent loss. I had placed the amount of damage in this vicinity not below $20,000."—George Angell.

off, but there will be many growing branches in lower part after pruning. There is much wreckage of branches everywhere. Many trees are entirely lost, many will be partly saved, although it will be years before they will be worth as much as before."—John B. Harrison.

Peacock, Mich.: "The storm was the worst ever known here. Nearly all trees had their tops broken off or the entire tree broken down."—Albert Spencer.

Gaylord, Mich.: "All maple shade trees are badly broken and the poplars almost wholly stripped."—C. J. Franks.

Whittemore, Mich.: "Fruit trees were broken down and practically ruined, especially cherry trees, many of which were broken off within 2 feet of the ground. The top branches of all shade trees were broken off."—C. H Berdeslee.

Arcadia, Mich.: "Older fruit trees, including plum, cherry, and apple trees, 30 years old and older, were 90 per cent loss in this section. Ash, maple, and elm trees are practically ruined as far as appearance is concerned."—L. K. Putney & Son.

The storm a little further north of the region of greatest damage is described very well by the cooperative observer at Traverse City, Mich., Mr. E. J. Liddy. He states: "This storm began in this section about 8 p. m., February 21, with coarse, granular sleet. The granules averaged about one-fourth the size of a pea. This continued nearly all day of the 22d and at 10 p. m., that night, it turned to rain. About 8 to 10 inches of this granular snow fell. After about four hours of heavy rain during the night of the 22d and 23d it turned cold, freezing a crust 3 to 4 inches think on the snow. Then, on the 23d, beginning about 7 a. m., it snowed 2 to 3 inches of fine snow on the top of the crust."

Heavy snow was general in the extreme northern counties of the lower peninsula and throughout the upper peninsula. The greatest depth reported was 33 inches, at Ispheming, Mich. The snowstorm was attended by strong northeast winds, reaching a velocity of 46 miles an hour at Houghton, Mich., and 48 miles per hour at Escanaba, Mich., which drifted the snow to great depths in places. The railroads were completely blocked for several days, as the weather continued cold throughout the rest of the month.

ON THE DESIGN OF RAIN-GAGES.

By S. P. FERGUSSON.

[Weather Bureau, Washington, D. C., February 20, 1922.]

The following statement of the requisites of rain-gages approved by the British Meteorological Office is abridged from an editorial having the above title published in the *Meteorological Magazine* of July, 1921, omission having been made of paragraphs relating wholly to British usage. This information is of great value everywhere, and particularly so in America because of the rapidly increasing interest in the measurement of precipitation, and the fact that many of the objectionable forms of gages referred to are in use and are offered for sale in the United States and other American countries:

The existence of a large body of voluntary and self-equipped observers of rainfall in the British Isles carries with it, among a multitude of advantages, the disadvantage that it is extremely difficult to eliminate the use in many cases of rain gauges of undesirable patterns. Such gauges are not infrequently obtained by persons interested in rainfall observing, but unaware of the errors to which they are likely to give rise. The collective experience of those who have made rainfall observing a special study is unequivocally in favor of the universal adoption of the now-recognized standard patterns of rain gauge and the rejection of certain obsolete patterns.

There are unfortunately price-lists, even amongst those issued by the well-known makers of rain gauges, which include particulars of gauges which have been definitely proved to be unsuitable for accurate measurement of rainfall. It is understood, however, that there is a certain market for obsolete types of rain gauges such as the "Howard" and the "British Association," which are unsatisfactory for measuring heavy rain and snow because of the absence of the deep cylindrical rim above the collecting funnel, and are also open to other objections. In the same way the well-known "Glaisher" gauge is still frequently listed and sold, although it has been clearly proved to be liable to develop serious errors.

It therefore seems desirable that the essential characteristics of a reliable rain gauge should be briefly explained for the guidance of purchasers who may not be aware of the defects inherent in some of the listed instruments. The prototype of the approved gauge [of the Meteorological Office] is the "Snowdon" rain gauge. The "Meteorological Office" pattern gauge, the "Bradford" gauge, and the "Seathwaite" gauge are variants of this type which embody the essential features of the "Snowdon" gauge, and are therefore also satisfactory. Most other gauges are unsatisfactory in that they do not contain the essential features, which may be stated as follows:

(1) The stout brass turned ring terminating upwards in a knife-edge, exactly 5 or 8 inches in diameter, which forms the rim of the gauge.

(2) The vertical cylinder 4 to 6 inches deep, extending from the rim to the upper edge of the funnel, which is intended to retain snow and hail, to prevent the outsplashing of rain which has fallen upon the funnel and to reduce to a minimum the risk of loss due to wind eddies.

(3) An inner collecting vessel, which can be removed for measuring the fall without disturbing the body of the gauge. Taps for drawing off water are extremely objectionable.

(4) Provision for a depth of at least 6 inches of the body to be firmly fixed in the ground.

(5) Simplicity of construction and avoidance of the use of rivets.

(6) Strength and durability.

(7) A capacity of not less than 10 inches of rain for a daily gauge. Gauges for monthly readings should be larger according to the district in which they are to be used.

Drawings of some of the gauges referred to will be found in "Rules for Rainfall Observers," a copy of which will be forwarded to any address * * *, on application to the superintendent of the British Rainfall Organization [London, England]. "The Observer's Handbook" of the [British] Meteorological Office may also be consulted.

The above conditions, with the exception of that numbered (3), apply generally also to self-recording rain gauges, it being noted, however, that the diameter of the rim of modern British recording gauges is usually either 6, 8, or 11 inches. Condition (5) is most important, and the following further desiderata apply:

(8) The scale values of the chart must conform accurately with the indications of the instrument.

(9) It is desirable that the hour lines on the chart should be straight and not curved.

(10) It is desirable that the scale value for rainfall should be not less than six times the natural scale, and that the drum should make a complete revolution in 24 hours.

(11) Dial gauges, tipping-bucket, and electrical-recording rain gauges are not in general suited to modern requirements.

(12) Should the mechanism of the gauge include an automatic syphon, the design and construction of the syphon require special care; the liability to failure of syphons is a serious drawback.

(13) Space should be available inside the case of the instrument for the insertion of a small oil lamp or a night light to warm the gauge in frosty weather.

Makers of rain gauges could materially assist in the extermination of undesirable types of rain gauge by refraining, in the interests of science as well as in their own ultimate interests, from making and listing any instrument which is known to be unsuitable for measuring or recording rainfall.

Intending rainfall observers, or existing observers who have the intention of re-equipping themselves with new gauges, are advised to insist that goods should be accompanied by certificates of accuracy. These certificates not only ensure the accuracy of the construction, but also give a guarantee that the gauge is of the approved pattern.

The writer's long experience in the use of recording gages in New England and in the mountains of the West indicates that condition (10) may be modified to advantage when a recording-gage for general use is designed. Since (1), 0.01 inch is the smallest quantity that may be measured with reasonable accuracy and (2), errors of exposure, etc., often cause errors much larger than 0.01 inch, it will be sufficient that the instrument be capable of recording definitely this minimum quantity, a refinement easily accomplished by the use of a scale of two to one or even smaller. (See paper on Improved Gages for Precipitation in this REVIEW, July, 1921, **49**:379-386.) The devices referred to in (11) and (12) should be definitely excluded from consideration except under circumstances where no others are available. Their complexity and large cost also are considerations. The tipping-bucket is useful when, for convenience, a record is desired at a distance from the collector, but requires care. Condition (13) is unnecessary in weighing rain- and snow-gages.

CORRELATION BETWEEN WIND VELOCITIES AT THE SURFACE AND THOSE IN THE FREE AIR.

By LEROY T. SAMUELS, Meteorologist.

[Weather Bureau, Washington, D. C., March 30, 1922.]

SYNOPSIS.

Correlation coefficients between wind velocities at the surface and those at various heights up to 3,000 meters have been computed from kite records made at Broken Arrow, Okla., Drexel, Nebr., Ellendale, N. Dak., Groesbeck, Tex., and Royal Center, Ind., after first classifying the data by surface wind direction. In all cases where the correlation coefficient showed a significant value of 0.50 or more, with a relatively small probable error, the regression coefficients were determined for computing the velocities aloft from those at the surface.

The residuals for each group (i. e., each surface direction for which a correlation coefficient of 0.50 or more was obtained), when the observed velocities were subtracted from the computed, were found to be practically indentically distributed and were therefore regarded as homogeneous. In view of this, they were all grouped together and a frequency polygon drawn. This exhibited a slight skewness and therefore the normal curve of error was not strictly applicable. This is shown, however, in the diagram. A smooth curve was fitted by inspection, since it was thought that all practical purposes would be served by merely showing graphically the degree of probability of a certain variation in the computed velocity from the actual. The arithmetic mean (disregarding signs) of the residuals was found to be 2.8, the median, zero class, and the mode, +2 class.

INTRODUCTION.

Increasing interest is being manifested as time goes on in weather conditions in the free air, due principally to the steady advancement being made in aeronautics and the consequent demand for meteorological information. Any possible short and direct methods of determining existing conditions aloft are therefore urgently needed. Considerable progress in various branches of meteorology is being made under this pressure of demand, and the outlook continues encouraging. Much of this progress, however, is limited to our ability to obtain numerous free-air observations, and this ability in turn to the available funds for carrying on the work.

OBJECT AND METHOD OF THE STUDY.

The determination of the linear correlation between two variables serves as a basis for the least-square computation of one variable in terms of the other. Obviously then, free-air wind velocities can be determined, within limited degrees of accuracy, if a significant degree of correlation exists between them and the velocities at the surface. This principle is being successfully applied in various branches of meteorological investigation, such as in predictions of morning minimum temperatures from the depression of the dew point at the preceding evening observation; and estimates of crop yields from monthly rainfall distributions.[1] So far as known this method has never been used, however, in computing free-air wind velocities from those at the surface.

Coefficients of correlation for surface and upper-wind velocities have, however, been computed from a comparatively small number of observations made at Avesnes le Comte and St. Omer in France. These values were close to 0.75 (the probable errors not given) when surface winds were correlated with those at various heights up to 3,000 feet. No classification by wind direction was made in these, however, there being available only some 30 and 60 pilot-balloon observations, respectively.[2]

Many empirical methods have been suggested for computing the velocity aloft but probably none has ever proved of sufficient reliability for practical purposes. Nearly all have been based on only a few observations and when used give exceedingly inaccurate results for individual cases.

Velocities a short distance above the ground may be computed from the formula,[3]

$$V=v\sqrt{\frac{H+22}{h+22}},$$

where V is the velocity (m. p. s.) of the wind at the height H (about 16 meters) above ground, computed from the known velocity at the height h (2 to 8 meters) above ground.

The equation,

$$\frac{V}{v}=\left(\frac{H}{h}\right)^{0.25},$$

was found by Douglas[4] to fit his observations for heights between 100 and 600 meters fairly well.

Shaw[5] suggests as a likely formula,

$$V=\frac{H+a}{a}\times V_0$$

in which V is the velocity at the height H above ground, V_0 the observed anemometer velocity, and a a constant, obviously dependent upon surrounding topography, anemometer exposure, and perhaps other factors. The formula is supposed to apply only until the gradient velocity is reached.

In addition to these and numerous other empirical equations, mention should be made of the expressions obtained by Taylor[6] and others from the hydrodynamical theory of turbulent motion.

The writer has computed the correlation coefficients between velocities at the surface and those at various levels up to 3 kilometers above mean sea-level (M. S. L.) classifying the winds according to surface direction. Those having a significantly high coefficient of correlation (0.50 or greater with a probable error less than one-sixth of the coefficient) were segregated and the regression equations determined from which the upper wind velocity is computed in terms of that at the surface.

Kite records obtained at Broken Arrow, Okla., Drexel, Nebr.; Ellendale, N. Dak.; Groesbeck, Tex.; and Royal Center, Ind., were used and classified by surface wind direction. The four cardinal points, N., E., S., and W., were regarded as sufficient for the purpose but where the number of available observations for these directions was too small to give a reliable coefficient of correlation, the adjacent directions (to 16 points) were included in sufficient quantity to bring the total number up to that necessary to give a dependable value. This is indicated in figure 1 by brackets inclosing the directions which were so grouped.

It has been suggested that possibly a better grouping would have resulted if the records had been classified according to the various quadrants of high and low pressure areas in which they were made. This may be true, but such a classification would require a much greater number of records since only those in well-developed HIGHS and LOWS could be used. Furthermore, the quadrant classification would defeat the essen-

[1] Smith, J. Warren. MO. WEATHER REV., SUPPLEMENT No. 16, 1920.
[2] *The Computer's Handbook.* M. O. 223, Section V, p. 67.
[3] Stevenson, *Jr. Scot. Metr. Soc.*, p. 348-1880.
[4] *Nature*, 33, p. 593, 1885.
[5] *Adv. Com. for Aero.*, R. & M. No. 9, p. 8, 1909.
[6] *Phil. Trans.*, V. 215, p. 1, 1915.

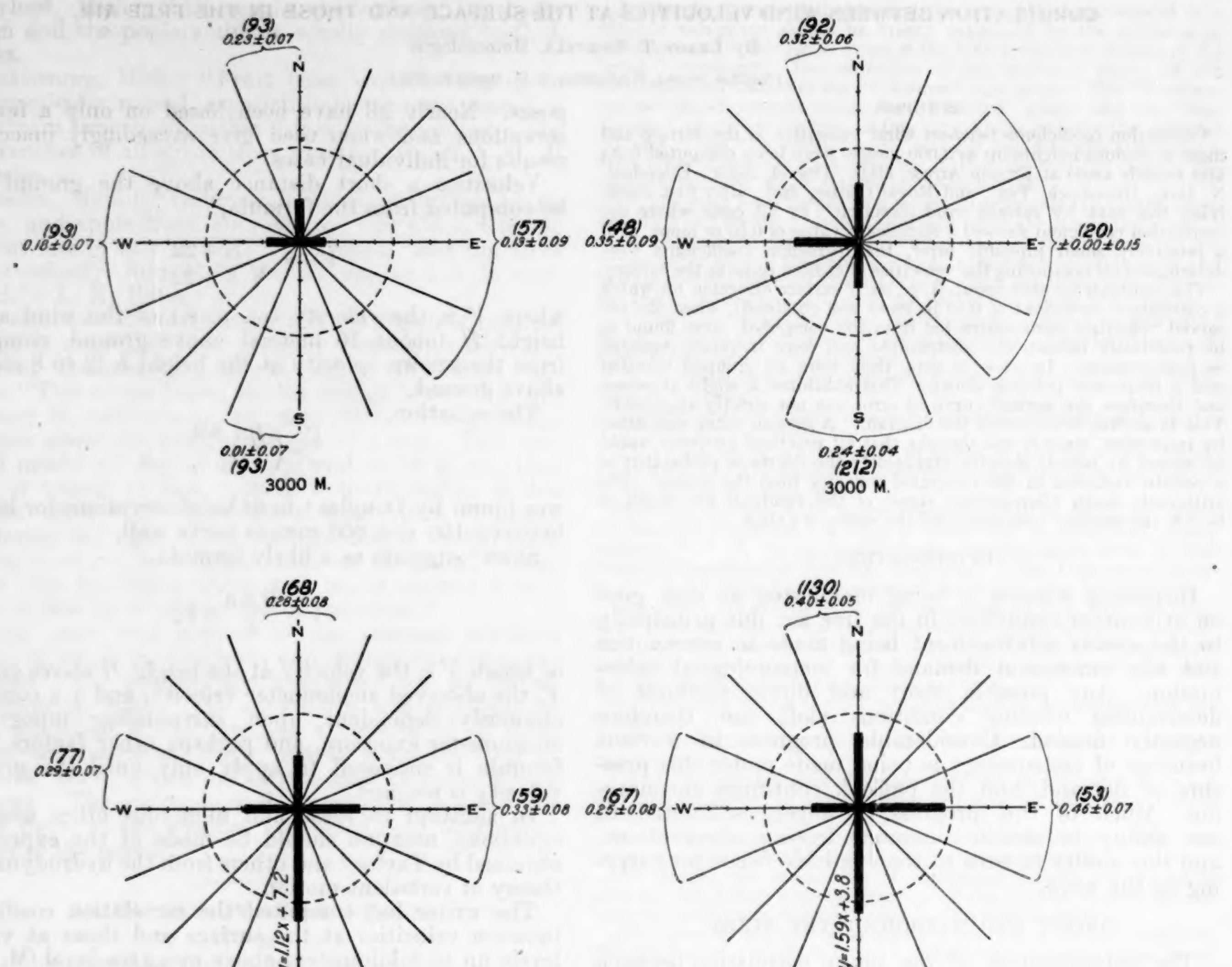

FIG. 1.—Correlation coefficients for surface-wind velocities and those in the free air at heights of 1,000, 2,000, and 3,000 meters above sea level, at Drexel, Nebr., with related data.

tial end desired, viz, the possibility of readily computing the velocity aloft when only the surface velocity and direction are known. In the other case it would be necessary to know the surrounding surface-pressure distribution.

The spring and winter seasons and summer and autumn seasons were taken together, first, because of the insufficient number of observations in any single season, and, second, because of the seasonal lag in velocities as shown in the means, autumn velocities being less than those in the spring.

The midway direction through which the surface wind turned during the kite flight was taken as the surface direction in this classification. Pilot-balloon records were not included in this study, but it is hoped to incorporate these data in a similar study some time in the future.

The correlation coefficients were computed by the usual formula, viz.

$$r=\frac{\Sigma(xy)}{n\sigma_x\sigma_y}, \qquad (1)$$

in which the x's are the series of deviations from the arithmetic mean of one series and the y's the corresponding deviations from the arithmetic mean in the other series. In this case the surface velocities correspond to the x's and the upper velocities to the y's.

In each case where the correlation coefficient was found to be 0.50 or higher with a relatively small probable error, the regression equation was determined. This equation is of the type, $y=bx$; the regression coefficients are determined by the equations,

$$b_1=r\frac{\sigma_x}{\sigma_y}, \qquad (2)$$

$$\text{and} \qquad b_2=r\frac{\sigma_y}{\sigma_x}, \qquad (3)$$

respectively. The equation of the straight line defined by the coefficient of correlation and expressing the direct relation of the surface and the upper wind velocity is[7] where

$$y=r\frac{\sigma_y}{\sigma_x}x, \qquad (4)$$

r, is the correlation coefficient, x, the surface wind velocity, y, the upper velocity. σ_x and σ_y, the standard deviations of the surface and upper wind velocities with respect to their arithmetic means, respectively. For practical purposes as explained by Yule[8] it is more convenient to express the equations in terms of the absolute values of the variables rather than the deviations; therefore replacing x by (X minus the arithmetic mean of x, for each particular group of x's) and y by (Y minus the arithmetic mean of y, for each particular group of y's), thereby changing the regression equation, $y=bx$, to the ordinary form of an equation for a straight line, $y=bx+a$.

As an illustration, let us take the south surface winds for spring and winter at Drexel, Nebr. Let it be desired to obtain an equation whereby the wind velocity at the height of 1,000 meters (M. S. L.) may be computed from the surface velocity when the wind direction is from the south. The velocities at the surface and the corresponding velocities at 1,000 meters (M. S. L.) are tabulated a: in Table I, the surface velocities being designated x and the upper velocities y. The departures of each value of x and y are then found from their respective arithmetic means and are tabulated under the columns headed A and B, respectively.

Thus we have when substituting in equation (1),

$$r=\frac{811.04}{77\times2.70\times5.60}=0.70$$

as the value of the correlation coefficient for these data.

[7] Marvin, C. F. MO. WEATHER REV. October, 1916, 44: 567.
[8] Yule, G. U.: *Introduction to the theory of statis,tics p. 179.* 1916.

TABLE 1.—*Computation of correlation coefficient for wind velocities at the surface and those at 1,000 meters above sea level at Drexel, Nebr. (surface direction, south) spring and winter.*

Surface velocity.	y 1,000 meter velocity.	x Surface velocity.	y 1,000 meter velocity.	x Surface velocity.	y 1,000 meter velocity.	A.	A.	A.	B.	B.	B.	A²	A²	A²	B²	B²	B²	A×B.	A×B.	A×B.
4	7	6	8	5	11	−2.8	−0.8	−1.8	−7.4	−6.4	−3.4	784	64	324	5,476	4,096	1,156	+2,072	+512	+612
6	12	5	9	6	16	−0.8	−1.8	−0.8	−2.4	−5.4	−1.6	64	324	64	576	2,916	256	+192	+972	−128
9	14	6	15	8	21	+2.2	−0.8	+1.2	−0.4	+0.6	+6.6	484	64	144	16	36	4,356	−88	−48	+792
10	18	9	21	5	16	+3.2	+2.2	−1.8	+3.6	+6.6	+1.6	1,024	484	324	1,296	4,356	256	+1,152	+1,452	−288
7	12	10	21	7	14	+0.2	+3.2	+0.2	−2.4	+6.6	−0.4	4	1,024	4	576	4,356	16	−48	+2,112	−8
5	8	4	11	5	17	−1.8	−2.8	−1.8	−6.4	−3.4	+2.6	324	784	324	4,096	1,156	676	+1,152	+952	−468
9	25	6	9	6	14	+2.2	−0.8	−0.8	+10.6	−5.4	−0.4	484	64	64	11,236	2,916	16	+2,332	+432	+32
5	11	3	10	14	24	−1.8	−3.8	+7.2	−3.4	−4.4	+9.6	324	1,444	5,184	1,156	1,936	9,216	+612	+1,672	+6,912
5	9	5	20	5	7	−1.8	−1.8	−1.8	−5.4	+5.6	−7.4	324	324	324	2,916	3,136	5,476	+972	−1,008	+1,332
5	9	4	10	13	24	−1.8	−2.8	+6.2	−5.4	−4.4	+9.6	324	784	3,844	2,916	1,936	9,216	+972	+1,232	+5,952
9	19	9	20	9	19	+2.2	+2.2	+2.2	+4.6	+5.6	+4.6	484	484	484	2,116	3,136	2,116	+1,012	+1,232	+1,012
9	21	7	14	5	9	+2.2	+0.2	−1.8	+6.6	−0.4	−5.4	484	4	324	4,356	16	2,916	+1,452	−8	+972
13	21	5	12	4	7	+6.2	−1.8	−2.8	+6.6	−2.4	−7.4	484	324	784	4,356	576	5,476	+4,092	+432	+2,072
8	11	4	9	8	14	+1.2	−2.8	+1.2	−3.4	−5.4	−0.4	3,844	784	144	1,156	2,916	16	−408	+1,512	−48
7	13	4	7	5	7	+0.2	−2.8	−1.8	−1.4	−7.4	−7.4	4	784	324	196	5,476	5,476	−28	+2,072	+1,332
10	17	5	12	6	12	+3.2	−1.8	−0.8	+2.6	−2.4	−2.4	1,024	324	64	676	576	576	+832	+432	+192
5	9	7	19	6	13	−1.8	+0.2	−0.8	−5.4	+4.6	−1.4	324	4	64	2,916	2,116	196	+972	+92	+112
7	19	4	17	11	21	+0.2	−2.8	+4.2	+4.6	+2.6	+6.6	4	784	1,764	2,116	676	4,356	+92	−728	+2,772
6	12	7	18	9	21	−0.8	+0.2	+2.2	−2.4	+3.6	+6.6	64	4	484	576	1,296	4,356	+192	+72	+1,452
18	23	4	15	9	17	+11.2	−2.8	+2.2	+8.6	+0.6	+2.6	12,544	784	484	7,396	36	676	+9,632	−168	+572
5	7	6	16	4	9	−1.8	−0.8	−2.8	−7.4	+1.6	−5.4	324	64	784	5,476	256	2,916	+1,332	−128	+1,512
7	12	4	7	5	21	+0.2	−2.8	−1.8	−2.4	−7.4	+6.6	4	784	324	576	5,476	4,356	−48	+2,072	−1,188
6	14	8	22	5	3	−0.8	+1.2	−1.8	−0.4	+7.6	−11.4	64	144	324	16	5,776	12,996	+32	+912	+2,052
11	18	8	30	6	16	+4.2	+1.2	−0.8	+3.6	+15.6	+1.6	1,764	144	64	1,296	24,336	256	+1,512	+1,872	−128
10	23	8	13	4	10	+3.2	+1.2	−2.8	+8.6	−1.4	−4.4	1,024	144	784	7,396	196	1,936	+2,752	−168	+1,232
7	7	4	7	......	......	+0.2	−2.8	......	−7.4	−7.4	......	4	784	......	5,476	5,476	......	−148	+2,072	......
Total.	......	......	......	525	1,106	......	......	......	......	......	......	......	......	560.88	......	......	2,407.92	......	......	+811.04
Means.	......	......	......	6.8	14.4	......	......	......	......	......	......	......	......	7.28	......	......	31.27	......	......	......
Sq. rts.	......	......	......	......	......	......	......	......	......	......	......	......	......	2.70	......	......	5.60	......	......	......

$$r=\frac{\Sigma(xy)}{n\sigma_x\sigma_y}=\frac{811.04}{77\times2.70\times5.60}=0.70. \qquad P.\ E.=0.674\,\frac{1-r^2}{\sqrt{n}}=0.674\,\frac{1-.4900}{\sqrt{77}}=\pm0.04.$$

The probable error of this coefficient is,

$$P.E. = 0.674\frac{1-r^2}{\sqrt{n}} \quad (5)$$

where, n is the number of observations upon which it is based. Substituting in formula (5), we have,

$$P.E. = 0.674\ \frac{1-.4900}{\sqrt{77}} = \pm 0.04$$

Since it is desired to compute the upper wind velocity or y, in terms of the surface velocity or x, equation (3) is used.[9]

Therefore the regression equation $y = bx$, becomes

$$y = r\frac{\sigma_y}{\sigma_x}x, \quad (4)$$

Substituting the computed values from Table 1 in equation (4), we have

$$y = 0.70\frac{5.60}{2.70}x \text{ or}$$

$$y = 1.45x \quad (6)$$

But in order to obtain an equation of a straight line in the usual form,[10] i. e., $y = bx + a$, we replace x in equation (6) by $X-6.8$ (the arithmetic mean of the surface winds) and y by $Y-14.4$ (the arithmetic mean of the upper winds), as found in Table I. Then substituting in equation (6) we have,

$$Y = 1.45X + 4.5 \quad (7)$$

It must be understood, of course, that the law of relation represented by the equation is purely an arbitrary one and applies only to conditions within the range of the records discussed. The degree of dependence which may be given the results obtained by these equations will be discussed later.

The above procedure has been carried out in a like manner for other stations and cases, but, as already stated, the regression coefficients have been found only when the coefficient of correlation was 0.50 or higher, with a small probable error, as useful results could not be expected where only a poor or no correlation existed.

Figure 1 shows these results graphically for Drexel, Nebr., and a little study of this chart will make comparison simple. In order to assist in this respect, superposed bars, with lengths proportional to the correlation coefficient, have been drawn to visualize the degree of correlation for the various altitudes and surface directions.

The correlation coefficients together with their probable errors are shown adjacent to the surface direction or group of directions to which they apply.

Regression equations (in which x = surface velocity and y = velocity aloft) for computing the upper wind velocities are shown along with the correlation coefficient whenever the latter has a significantly high value of 0.50 or more.

The figures in parentheses indicate the number of observations upon which the correlation coefficient is based.

Lack of space prohibited showing these data graphically for the other stations, but the data themselves are given in tabular form in Table 2. The column headings in this table are explained as follows: Column headed "wind direction" gives the surface direction for which the correlation coefficient was computed. In cases where more than one direction occurs, an insufficient number of observations from the cardinal direction, i. e., N., S., E., or W., was available and the adjacent directions were therefore included; thus, extreme directions only of such groupings are indicated; n indicates the number of observations upon which the correlation coefficient is based, r shows the correlation coefficient and its probable error, and y represents the wind velocity aloft and is that value found by the regression equation shown in this column, x representing the surface wind velocity. No regression equation is shown for correlation coefficients less than 0.50, as previously explained.

Figure 3 shows how these computations may be obtained graphically by drawing the regression line on coordinate paper. The line in the figure is that for south surface winds at Drexel, Nebr., for spring and winter when surface velocities were correlated with those at 1,000 meters above sea level. For example, to find the upper velocity with a surface velocity of 8.7 m. p. s. from the south we find 8.7 on the horizontal scale and run up to its intersection with the regression line and read across on the vertical scale 17.1 m.p.s., the same as is obtained when 8.7 is substituted in the regression equation $y = 1.45x + 4.5$.

It will be noticed that for Drexel and Ellendale the 1,000 meter (M. S. L.) level was chosen while for the other stations, the 750 meter (M. S. L.) level was taken. This was done because of the difference in elevation above sea-level of the stations themselves. Thus for the three lower stations the 750 meter (M. S. L.) level is practically the same height above the *surface* as the 1,000 meter (M. S. L.) level is above the surface at Drexel and Ellendale, the higher stations.

A few remarks regarding the interpretation and significance of correlation coefficients and their reliability as measures of relationship seem appropriate.

The function of the correlation coefficient is that of an index of the extent to which the relation between certain data may be represented by a straight line. A low correlation coefficient must not necessarily be interpreted to mean no relation, but that if a relation exists it is either small or is not well represented by a straight line.[11] The value by the very nature of the equation itself can never be greater than unity, i. e., $+1$ and -1, indicating perfect correlation, positive in the first case and negative or inverse in the second, while 0 indicates no correlation. The following rules will assist in giving a general idea of the interpretation of the correlation coefficient, r, according to its relation to its probable error.

1. If r is less than the probable error, there is no evidence whatever of relation.
2. If r is more than 6 times the probable error, the existence of correlation is a practical certainty.
3. When the probable error is relatively small a value for r of less than 0.30 can not be considered to indicate correlation at all marked, while a value of more than 0.50 is evidence of good correlation. Mr. W. H. Dines, of the British Meteorological Office, points out, however, that in forecasting one variable in terms of the other, too much dependence should not be placed on a correlation coefficient as low as 0.50, even though the probable error is relatively small. He shows that, "If there is a cause A and a result M with a correlation r between them, then in the long run A is responsible for r^2 of the variation of M."[12] Obviously, then, on the average, with a

[9] Marvin, C. F., *loc. cit.*
[10] Yule, G. V, *loc. cit.*
[11] Marvin, C. F. Mo. WEATHER REV. October, 1916, 44:560.
[12] *Meteorological Magazine*, February, 1921, p. 20.

correlation of 0.50, only 25 per cent, i. e. (0.50),[2] of the causes of the changes in the variable can be attributed to the correlated associate.

The striking feature shown in Figure 1 for Drexel and in Table 2 for all stations is the generally high correlation existing between the velocities at the surface and those between 500 and 600 meters above. The coefficients indicate a somewhat better relation during the spring and winter than during the summer and autumn. Groesbeck, the station farthest south, shows the least correlation for this level, the coefficients being less than 0.50 for all directions, except north for both periods and west for spring and winter.

The 2,000 meter level does not indicate nearly as good correlation as does the lower level. This is to be expected, since the wind at the higher levels becomes more and more influenced by other factors, which in turn do not influence the winds at the surface to such a great extent. The south surface winds at Drexel for this level maintain high correlation coefficients for both periods, and the same is true for these winds at Broken Arrow for the spring and winter. Groesbeck has a significant value for north and west surface winds for spring and winter for this level.

The correlation coefficients for 3,000 meters were computed for Drexel and Ellendale, there being too few observations at the other stations for this purpose. No values as high as 0.50 were found, but the west surface winds at Ellendale for spring and winter gave a surprisingly high value of 0.44 ± 0.08. A significant feature of nearly all the values for this level was the extremely low degree of correlation, some directions indicating zero while others showed a small negative value.

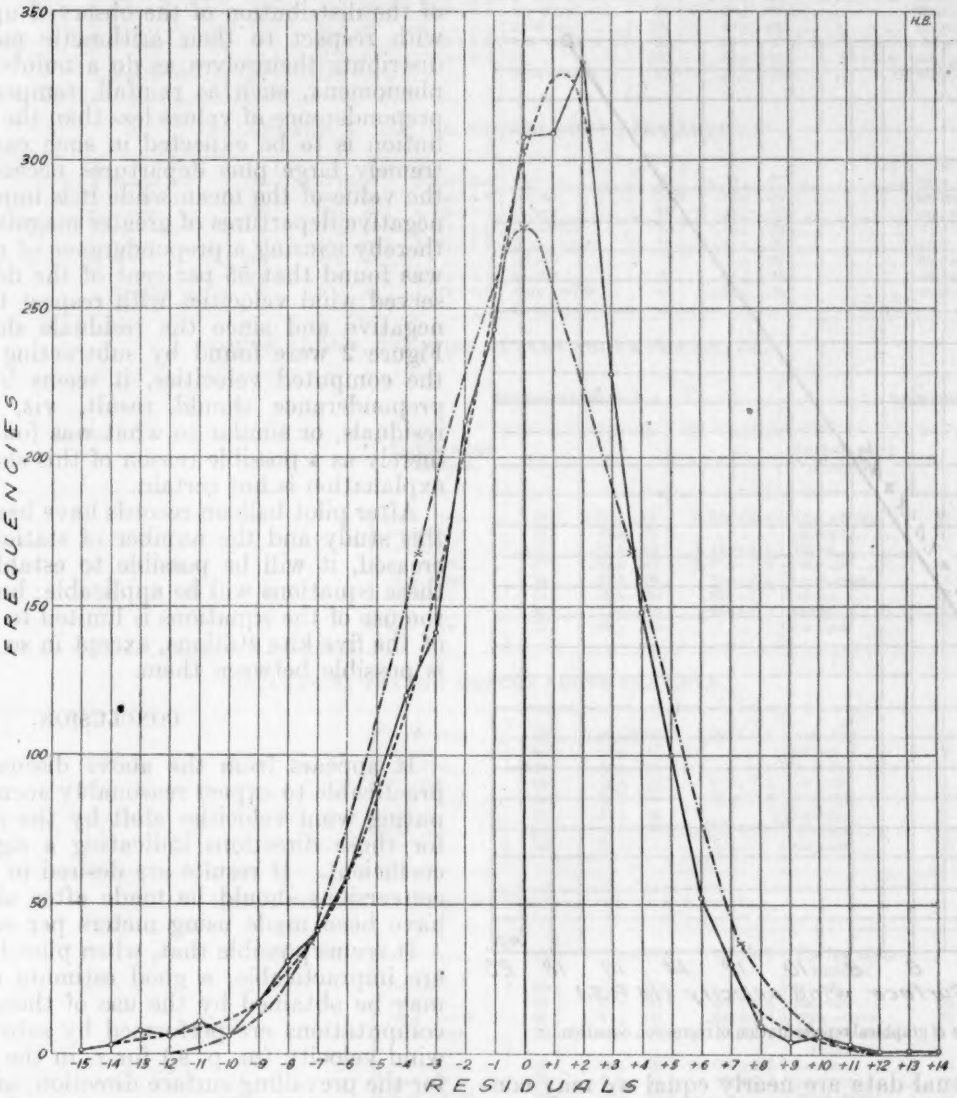

FIG. 2.—Frequency polygon showing the distribution of the residuals. m. p. s. (computed minus observed velocities).

PROBABLE ACCURACY TO BE EXPECTED.

When using equations such as these there is always a degree of uncertainty as to the correctness of the computed result in individual cases. Statistics furnish various methods of determining the probability within certain limits of accuracy when the data fall in the category of normal distributions. Attempt will be made to show to what extent this is true in our study.

The wind aloft was computed from the surface velocity by the regression equation whenever the latter was determined. The residuals of these computed velocities were then found by subtracting the observed from the computed. These residuals for the winds of the various directions were then charted as a histogram, and it was

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found that the different groups were nearly identical as to distribution. The data were therefore regarded as homogenous and a single group was made of all. Figure 2 is the resulting frequency polygon.

The great number of observations (2,522) included in this graph justifies its acceptance as typical and representative. It is apparent that the distribution is not symmetrical. Nevertheless, the normal curve of best fit to the data is shown on the drawing by the dot-and-dash line. Since the maximum height of this normal

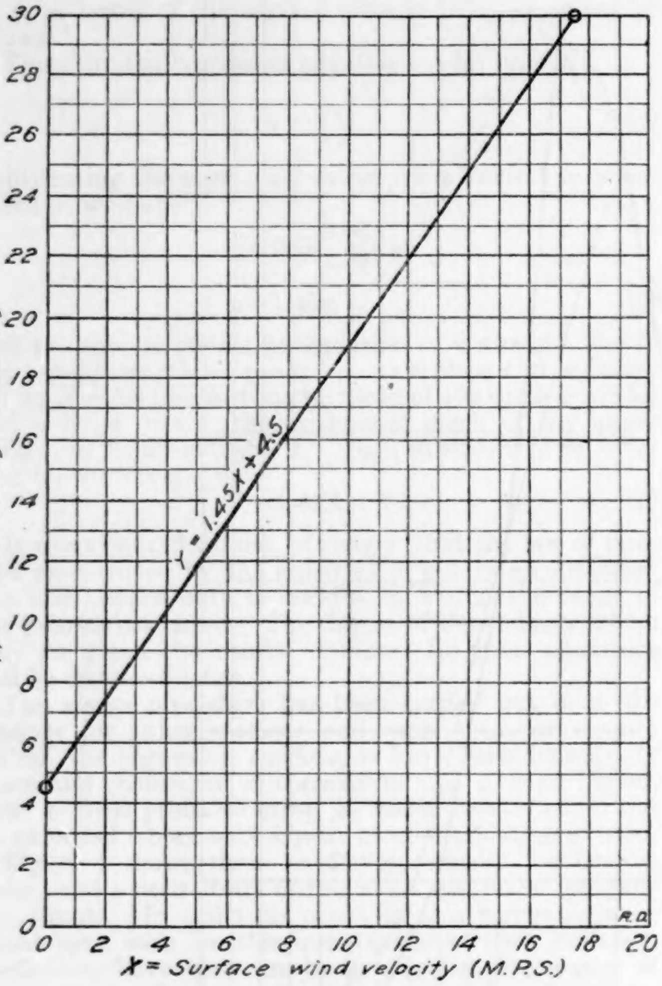

FIG. 3.—Example of graphical representation of regression equation.

curve and the actual data are nearly equal we may conclude that the data are comparatively elemental, although slightly askew.

In addition, it has seemed sufficient to draw by freehand a smooth asymmetrical curve fitting the observed data as closely as possible, in order to show the probability of residuals of different magnitude.

The significant fact brought out by this frequency polygon is the large proportion of computed velocities with small residuals and the extremely small percentage having large residuals.

The following values from these residuals were computed: Arithmetic mean (disregarding signs), 2.8, median, zero class, mode, +2 class. It was found that the sums of all plus and minus residuals were nearly equal, viz, +3557 and −3524, respectively. This small difference seems negligible. The number of plus residuals disregarding their size show a decided preponderence, amounting to 55 per cent of the total. This is apparent from the skewness exhibited in the graph. The reason for this skewness is not certain but seems probably to be a result of the distribution of the observed upper wind velocities with respect to their arithmetic means. These winds distribute themselves as do a number of meteorological phenomena, such as rainfall, temperature, etc., with a preponderence of values less than the mean. This distribution is to be expected in such cases, since a few extremely large plus departures necessarily tend to raise the value of the mean while it is impossible to have any negative departures of greater magnitude than the mean, thereby causing a preponderance of negative values. It was found that 55 per cent of the departures of the observed wind velocities with respect to their means were negative and since the residuals shown graphically in Figure 2 were found by subtracting the observed from the computed velocities, it seems likely that an equal preponderance should result, viz, 55 per cent plus residuals, or similar to what was found. This is offered merely as a possible reason of this skewness but the true explanation is not certain.

After pilot balloon records have been incorporated into this study and the number of stations consequently increased, it will be possible to establish zones in which these equations will be applicable; but until this is done, the use of the equations is limited to the general vicinity of the five kite stations, except in so far as interpolation is possible between them.

CONCLUSION.

It appears from the above discussion to be entirely practicable to expect reasonably accurate results in computing wind velocities aloft by the regression equations for those directions indicating a significant correlation coefficient. If results are desired in miles per hour, the conversions should be made after all the computations have been made using meters per second.

It seems possible that, when pilot-balloon observations are impracticable, a good estimate of the upper winds may be obtained by the use of these equations. These computations are performed by substituting the surface wind velocity (m. p. s.) for x, in the particular equation for the prevailing surface direction, and solving for y, the velocity aloft. These equations for their respective directions are given in Table 2. The erratic conditions found aloft with certain winds is fully realized but with an increasing amount of observational data available, the application of statistical treatment should prove of practical value in many ways.

Acknowledgment is due Mr. Edgar W. Woolard for information regarding statistical methods and to the employees of the Aerological Division for assistance rendered in checking the large amount of computational work.

TABLE 2.—*Correlation coefficients and related data for various stations and elevations.*

DREXEL, NEBR. (396 METERS ABOVE SEA-LEVEL).

Season.	1,000 meters (M. S. L.). Surface wind direction.	*n.*	*r.*	*y.*	2,000 meters (M. S. L.). Surface wind direction.	*n.*	*r.*	*y.*	3,000 meters (M. S. L.). Surface wind direction.	*n.*	*r.*	*y.*
Spring and winter	n.	91	0.61±0.04	$1.22x+5.9$	n.	68	0.28±0.08		nnw.-n.	93	0.23±0.07	
	ene.-ese	86	.73± .03	$1.42x+2.3$	ene.-ese	59	.33± .08		ne.-se	57	.13± .09	
	s.	77	.70± .04	$1.45x+4.5$	s.-ssw.	89	.60± .05	$1.12x+7.2$	s.-ssw.	93	.01± .07	
	wsw.-w	87	.50± .05	$.99x+7.1$	w.-wnw.	77	.29± .07		wsw.-wnw.	93	.18± .07	
Summer and autumn	n.	61	.38± .07		nnw.-n.	130	.40± .05		nnw.-n.	92	.32± .06	
	ene.-ese	86	.65± .04	$1.14x+3.6$	ene.-ese	53	.46± .07		ne.-se	20	.00± .15	
	s.	133	.75± .03	$1.93x+2.1$	s.	110	.56± .04	$1.59x+3.8$	sse.-ssw.	212	.24± .04	
	wsw.-wnw.	78	.43± .06		wsw.-wnw.	67	.25± .08		wsw.-wnw.	48	.35± .09	

ELLENDALE, N. DAK. (444 METERS ABOVE SEA LEVEL).

Season.	1,000 meters (M. S. L.). Surface wind direction.	*n.*	*r.*	*y.*	2,000 meters (M. S. L.). Surface wind direction.	*n.*	*r.*	*y.*	3,000 meters (M. S. L.). Surface wind direction.	*n.*	*r.*	*y.*
Spring and winter	n.-nne.	85	0.79±0.03	$0.85x+2.8$	nnw.-n.	79	0.35±0.07		nnw.-nne.	51	0.39±0.08	
	ne.-se.	71	.50± .06	$.75x+4.4$	ne.-se.	51	.18± .09		ne.-se.	22	.12± .14	
	s.-ssw.	103	.60± .04	$1.05x+4.4$	s.-ssw.	85	.29± .07		sse.-ssw.	63	− .02± .08	
	wsw.-wnw.	59	.60± .06	$1.11x+5.6$	sw.-wnw	70	.45± .06		wsw.-wnw.	41	.44± .08	
Summer and autumn	n.-nne.	90	.68± .04	$1.03x+2.2$	nnw.-nne.	78	.48± .06		nnw.-nne.	42	.14± .10	
	ne.-se.	105	.47± .05		ne.-se.	73	.28± .07		ne.-se.	31	.24± .11	
	s.-ssw.	109	.61± .04	$1.26x+3.4$	s.-ssw.	96	.47± .05		sse.-ssw.	78	.18± .07	
	w.-wnw.	73	.67± .04	$1.21x+4.0$	wsw.-wnw.	83	.38± .06		wsw.-wnw.	64	.20± .08	

BROKEN ARROW, OKLA. (233 METERS ABOVE SEA LEVEL).

Season.	750 meters (M. S. L.). Surface wind direction.	*n.*	*r.*	*y.*	2,000 meters (M. S. L.). Surface wind direction.	*n.*	*r.*	*y.*
Spring and winter	nnw.-nne.	70	0.60±0.05	$0.92x+2.4$	nnw.-nne.	38	0.32±0.10	
	ne.-se.	42	.48± .08		ne.-se.	23	.19± .14	
	sse.-ssw.	132	.65± .03	$1.13x+4.4$	sse.-s.	60	.52± .06	$0.99x+4.1$
	sw.-wnw.	50	.52± .07	$1.41x+1.3$	sw.-nw.	38	.10± .11	
Summer and autumn	nnw.-nne.	58	.57± .06	$.89x+3.1$	nnw.-nne.	26	.42± .11	
	ne.-se.	49	.59± .06	$.95x+3.7$	ne.-se.	27	.43± .11	
	s.	94	.57± .05	$.95x+4.2$	sse.-s.	98	.43± .06	
	sw.-wnw.	33	.46± .09		sw.-nw.	28	.27± .12	

GROESBECK, TEX. (141 METERS ABOVE SEA LEVEL).

Season.	750 meters (M. S. L.). Surface wind direction.	*n.*	*r.*	*y.*	2,000 meters (M. S. L.). Surface wind direction.	*n.*	*r.*	*y.*
Spring and winter	nnw.-nne.	93	0.68±0.04	$1.09x+2.6$	nw.-nne.	72	0.54±0.06	$1.10x+5.7$
	ne.-se.	68	.34± .07		ne.-se	38	− .09± .11	
	sse.-ssw.	124	.43± .05		s.-ssw.	89	.20± .07	
	sw.-nw.	68	.55± .06	$.77x+7.1$	sw.-nw.	55	.60± .06	$1.12x+7.1$
Summer and autumn	nnw.-nne.	61	.52± .06	$.86x+3.5$	nw.-nne.	38	.36± .10	
	ne.-se	78	.42± .06		ne.-se	41	.39± .09	
	sse.-ssw.	124	.46± .05		sse.-ssw.	99	.29± .06	
	sw.-nw.	58	.37± .08		sw.-nw.	42	.30± .09	

ROYAL CENTER, IND. (225 METERS ABOVE SEA LEVEL).

Season.	750 meters (M. S. L.). Surface wind direction.	*n.*	*r.*	*y.*	2,000 meters (M. S. L.). Surface wind direction.	*n.*	*r.*	*y.*
Spring and winter	nnw.-nne.	25	0.70±0.07	$1.21x+1.4$	Too few observations.			
	ne.-se.	65	.47± .07		ne.-se	34	0.19±0.11	
	sse.-ssw.	59	.59± .06	$1.48x+5.1$	sse.-ssw.	50	.36± .08	
	wsw.-wnw.	89	.67± .04	$.93x+4.4$	wsw.-wnw.	72	.30± .07	
Summer and autumn	nnw.-nne.	35	.49± .09		Too few observations.			
	ne.-se.	59	.53± .06	$1.08x+2.5$	ne.-se	24	− .23± .13	
	sse.-ssw.	75	.66± .04	$1.48x+2.8$	sse.-ssw.	54	.36± .08	
	wsw.-wnw.	99	.45± .05		wsw.-wnw.	81	.28± .07	

NOTES, ABSTRACTS, AND REVIEWS.

RADIO WEATHER REPORTING ON THE GREAT LAKES.

Following closely upon the establishment of the Pacific coast radio weather-reporting program by the Forecast Division of the Weather Bureau,[1] comes the announcement that this service will be amplified for the benefit of marine and aviation interests on the Great Lakes beginning April 15, 1922. This development is significant because it completes the service to all marine interests in waters contiguous to the United States whether in the Atlantic, Gulf of Mexico, Pacific, or Great Lakes.

In a circular issued April 1, 1922, this new service is described in detail. Concerning the major bulletins, it is announced that twice daily (noon and 11.30 p. m., seventy-fifth meridian time) between April 15 and December 20, the Great Lakes Naval Radio Station will broadcast on 1,988 meters wave length a message consisting of (1) the surface-weather conditions as observed at the preceding 8 a. m. or 8 p. m. observations, together with aerological observations taken in the morning or afternoon of the date of distribution; (2) a synopsis of general conditions, wind and weather forecasts for the upper and lower Lakes, storm warnings for the Lakes, and flying-weather forecasts for aviation zones extending between western New York, northern Ohio, and Indiana and western Kansas, Nebraska, and the Dakotas. Local bulletins will be distributed at various times of day from the naval radio stations at Alpena, Mich.; Buffalo, N. Y.; Chicago, Ill.; Cleveland, Ohio.; and Duluth, Minn.

These local bulletins apply to the particular Lakes near which the stations are located and consist largely of forecasts and storm warnings. Ships may call upon any of these stations for weather reports, warnings, or forecasts.

Copies of an appropriate base map for the plotting of weather data may be obtained free of charge by vessel masters from any Weather Bureau station on the Great Lakes.

Nearly coincident with the announcement of this new service comes the statement that on and after the opening of navigation in the Great Lakes all forecasts and storm warnings will be issued from the Chicago office of the Weather Bureau, instead of the Washington office as heretofore. In addition to this change, the States of Indiana and Michigan will be included in the Chicago forecast district.—*C. L. M.*

THE ANTITRADES.

By W. VAN BEMMELEN.

[Reprinted from *Nature*, Feb. 9, 1922, pp. 172–173].

The long series of pilot balloon ascents made at and near Batavia (lat. 6° 11′ S., long. 106° 50′ E.) during the years 1909–17 has given a fair knowledge of the system of air currents over west Java up to great heights. The general outcome of this investigation has been communicated to the Royal Academy of Science of Amsterdam.[1] My endeavor to explain that system led to a controversy between Doctor Braak and myself and Professor van Everdingen.[2] After renewed consideration of the problem I have come to new results which I propose to set out provisionally here.

In the memoir presented to the Amsterdam academy is inserted a synoptical table containing the mean directions and velocities of the wind for each month and for height intervals of 1 kilometer up to a height of 24 kilometers. In it the principal air currents have been made conspicuous by letter coloring and framing. They are:

First, the west monsoon prevailing during the southern summer in the bottom layers up to 5–6 kilometers.

Above it, up to 10–13 kilometers, blow easterly winds with southern components, which I would call trade-like winds. In the winter season such winds blow in the bottom layers up to 3 kilometers.

Above these trade-like winds blow antitrade-like winds, i. e., easterly winds with a northern component. Their upper limit reaches to 18 kilometers from December until March; it goes down to 12 kilometers in June, and again rises to the maximum height of 21 kilometers in October. The velocities show two maxima: In February at a height of 15 kilometers (12 meters per second) and in August at 14 kilometers (22 meters per second); in April they are very weak. Not only is their velocity a maximum, but also the transport of air mass.

Over the antitrade-like current appear again currents of trade-like character; however, from March until September an eastward moving air mass is embedded in them, reaching heights of 24 kilometers in *maximo*.[3] Very high balloon flights in March and September revealed the existence of strong (30–40 meters per second) easterly winds up to 30 kilometers.

Considering these results, three principal questions arise: (1) Are the trade-like winds real trades? (2) Is the antitrade-like current a true deflux from the Equator toward the subtropics? (3) Whence do the great velocities of the high antitrade-like and upper trade-like winds originate?

The currents mostly possess a stationary character, and consequently their directions will be in close agreement with the trend of the isobars in their level. For Java the latter will be conditioned by the neighborhood of the Australian continent. As in the southern winter over Australia is settled a circular HIGH, we may expect over Java the trend of the isobars to be ENE.–WSW. and the gradient to be toward the Equator. However, by friction with the earth surface the air blows across the isobars and takes an ESE.–WNW. direction. This means real outflow to the Equator; thus the trade-like wind mentioned above is a trade.

In the southern summer over Australia lies a LOW, causing the west monsoon, but above this LOW the gradient is reversed and a HIGH prevails. This causes in the same manner as mentioned above a trade-like wind. The friction required for it, I presume, is caused by the streaming one over another of the two currents with contrary directions (the west-east below, the east-west above). Thus, I think, the first of the three questions put forward has been answered in the affirmative: the trade-like winds are trades.

As to the second question, we may consider first the southern winter season. In it the gradient Australia-Java is reversed at the level of ±5 kilometers. But does it change too in the other season at 3 kilometers? Apparently not, because, going upward, the easterly winds do not then change to westerly ones; they back only from ESE. to ENE., while the velocity does not vanish. Now, admitting the absence of friction in these layers,

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[1] Cf. MO. WEATHER REV., January, 1922, 50:26.
[1] Proceedings, April 16, 1918.
[2] *Tijdschrift v. h. K. Aardrijkskundig Gen.*, vol. 35, 1918, No. 1, and vol. 36, 1919, No. 4.
[3] Owing to a typographical error in the synoptical table the velocities at the levels 18, 19, and 20 kilometers for June have wrongly been given as 1 meter per second instead of 10 meters per second.

and consequently assuming the current to follow the course of the isobars, we come to the conclusion that this course remains mainly the same when going upward, or the Australian HIGH subsists in these higher layers, though perhaps shifting somewhat to the eastward.

Accepting this, we may ask: Might it be that the antitrade-like current flows around the Australian HIGH, bringing about thus the deflux towards the subtropics?

In that case the antitrade-like current should be a true antitrade, although of local character. But then we are obliged to admit that a flux toward the Equator will also occur at the opposite side of the oval system of the Australian HIGH; only the deflux should surpass it by the mass of air (or part of it) which ascends from the surface in the equatorial belt.

This influx, too, may give us an answer to our third question: What is the cause of the great east-west velocities of antitrade-like and upper trade-like winds? Exner[4] points to the fact that ascension of air at the Equator is able to increase its east-west velocity only by a fraction, and, therefore, tries to explain the great velocities of high equatorial east winds by shifting of air from higher latitudes towards the Equator with preservation of rotational moment. A meridional shift from latitude $\pm 15°$ causes velocities from 30–40 meters per second.

My result for the antitrade-like current over Java is the same as that obtained by Sir Napier Shaw when calculating isobars for the level at 8,000 meters.[5] He, too, finds long-stretched HIGHS, and he speaks of the flowing of air around these HIGHS, by which the east-west wind velocities of the Equator act on the opposite currents of the subtropics as by chain-drive pulling.

However, through lack of data Sir Napier Shaw had to calculate his isobars by means of one and the same set of vertical temperature gradients for the whole hemisphere, which, of course, makes the results somewhat doubtful for the equatorial belt, because there the critical pressure differences at the 8,000-meter level are small only.

For that reason I have sought for another independent way to solve the antitrade problem, and I think I have found it by mapping the average directions of cirrus drift as observed in the equatorial belt.

Cirrus floats there at levels of about 11 kilometers, and at that height over Java the antitrade-like winds blow from May until October, while during the rest of the year winds with trade-like character prevail.

The mean directions of cirrus drift which were at my disposal (mostly borrowed from H. Hildebrandsson[6]) I plotted separately for winter and summer, and although they are very sparse I made an endeavor to construct lines of flow. The result is incorporated in the accompanying maps. (Fig. 1.) They should be regarded as a first trial; e. g., no attention was given to the density of the lines of flow, only to their direction. For three stations (Hawaii, Ascension, and Congo) only annual means were given, and they have been used for both summer and winter.

Trying to design the lines of flow, it was apparent this could be done only by assuming oblong systems to exist at both sides of the equator, together with a zonal stream winding about the equator. Of these ovals those lying over central America, northern Africa, and southern Asia correspond fairly well with the isobaric HIGHS found by Sir Napier Shaw at the 8-kilometer level.

[4] *Dynamische Meteorologie*, 1917, p. 182.

[5] Rede Lecture, *Nature*, July 21, 1921, p. 653. Sir Napier Shaw most kindly provided me recently with a copy of the unpublished *isobaric charts* which he constructed for the Northern Hemisphere.

[6] Les Bases de la Météologie, II. Also Nova Acta R. Soc. Sc. Upsaliensis, ser. 4, vol. 5, No. 1.

Estimating roughly the latitudes of the centers of the current ovals, I find—

Oval over.	Latitude of center.		Seasonal shift.
	Winter.	Summer.	
Central America	20 N.	28 N.	8
Northern Africa	8 N.	25 N.	17
Southern Africa	(?)	18 S.	....
Arabian Sea	....	0	....
Bengalese Sea	15 N.	....	....
East Asia	17 N.	30 N.	13
Australia	13 S.	10 S.	3
Mean	....	....	10

The mean latitude of the northern ovals is about 20°, that of the southern about 15°. At the surface of the earth pressure is highest in latitudes 35° N. and 30° S.; accordingly, when identifying the current ovals with pressure HIGHS, the latter are 15° nearer to the Equator at the 11-kilometer level than at sea level. This shifting is in agreement with the considerations of Teisserenc de

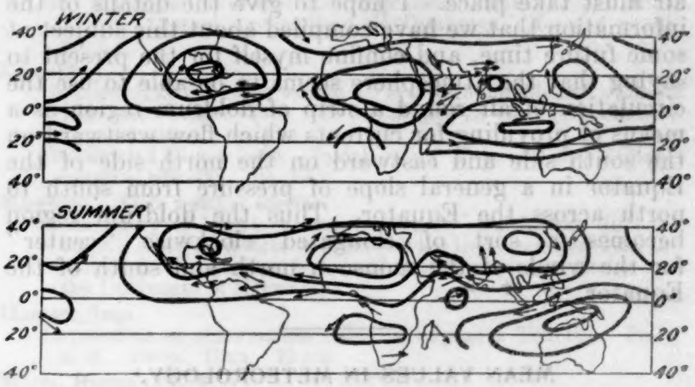

FIG. 1.—Lines of flow of cirrus drift.

Bort and Exner (loc. cit., p. 177), according to which the high-pressure belts with increasing height move toward the equator.

The mean amount of seasonal shifting found above, i. e., 10°, fairly agrees with the correspondence shifting of these high-pressure belts at the surface:

Northern belt:		Southern belt:	
January	32° N.	January	37° S.
July	39° N.	July	28° S.
Shift	7°	Shift	9°

Resuming, it seems probable that in high levels above the Equator and winding about it flows a zonal east-west current of stationary character, which is fed by ascending surface air and locally by air streaming in from higher latitudes, which, moreover, maintains its east-west motion. Also, that from it flows off in other places air to the subtropical belts; these currents of deflux bend from an east-west to a west-east direction.

This communication may prove anew that the knowledge of the direction of the cirrus drift in the equatorial belt is important for the investigation of atmospheric circulation between the Tropics, but that the observations at our disposal are few and rather insufficient. For that reason I appeal to those who are in the position to make these observations to supply this need.

To observe in what direction cirrus floats is easy and requires simple means only; moreover, observations are not confined to fixed hours or days. Thus they are particularly adapted to be made by amateurs living in the tropical regions.

DISCUSSION.

By Sir NAPIER SHAW.

[Reprinted from *Nature*, February 16, 1922.]

I am glad to support the appeal for observations of the motion of cirrus clouds in the intertropical region and elsewhere made by Professor van Bemmelen in his letter on the antitrades. (Nature, February 9, p. 172.) It is very interesting that the results which he has obtained by direct observation, with only such additional information from dynamics as may be got from a consideration of the general character of the Australian pressure, should coincide so excellently with results which we obtained here from the calculation of the distribution of pressure at various levels, and the assumption that wind flows along the isobars.

There are some details in Professor van Bemmelen's maps which indicate a flow of air across the Equator which I should be disposed to modify in view of the peculiar conditions under which such a transference of air must take place. I hope to give the details of the information that we have compiled about this subject at some future time, and confine myself for the present to saying that the atmosphere seems to be able to use the circulation of air round a strip of doldrum region as a means of providing for currents which flow westward on the south side and eastward on the north side of the Equator in a general slope of pressure from south to north across the Equator. Thus the doldrum region becomes a sort of elongated clockwise "center" for the winds of the monsoon north and south of the Equator. * * *

MEAN VALUES IN METEOROLOGY.[1]

By J. MASCART.

[*Comptes Rendes*, July 11, 1921, pp. 94-96.]

The average value, over a series of years, of the mean temperature of a particular day of the year is termed the "normal mean" for that day. The same term applies to any other meteorological element. It is pointed out that the formation of true "normal means" presents certain difficulties. A curve of daily "normal means" formed for given dates is not smooth, but presents singularities, some dates or groups of dates appearing specially favored. It is a matter for investigation to determine how far, if at all, these are real. The author finds that they arise, at least partly, through forming the "normal mean" for a given date instead of choosing that day in each year on which the earth traverses, as nearly as possible, the same portion of its orbit, which may occur on one of three consecutive dates according to the year. Utilizing 40 years' observations, and forming, on these lines, as a simple illustration, the frequency of occurrence of frost on each day of the year, a much nearer approach to a smooth curve is obtained than by adhering to the same "date" in each year. Normal means utilized in theoretical investigations should be formed on the suggested plan.—*M. A. G.*

[1] Reprinted from *Science Abstracts*, Jan. 31, 1922, p. 23, § 61.

THE BELGIAN DAILY WEATHER BULLETIN.

By J. JAUMOTTE.

[Abstracted from *Ciel et Terre*, May-June, 1921, vol. 37, pp. 69-74.]

The war caused an interruption to the publishing of weather bulletins in Belgium, owing to the restriction on the telegraph and the scarcity of money to carry on the work. The war had one good effect, however—that of increasing the number of stations, as the importance of meteorology to aviators is evident.

Belgium found itself in a very unfavorable condition, and has had to rely upon the cooperation of the Government radio posts, which may be discontinued as the country gets back to a peace-time basis. The weather report for Belgium was generally sent out from Uccle and relayed by the Eiffel Tower to all European receiving stations.

The weather maps now issued by the Royal Meteorological Institute of Belgium, are of a different type from that of those formerly issued.

These maps are on a Lambert projection, on a scale of $\frac{1}{10000000}$. The base is a relief map with contours for 200, 500, 1,000, 2,000, and 3,000 meters. On such a large scale map it is easy to indicate wind direction and velocity, pressures, temperatures (degrees C.), and state of the sky. Lines of equal barometric tendency are also published on these maps. On the margin of the map for 7 a. m. are small maps showing pressure and winds at the previous three observations at 1 a. m., at 6 p. m., and at 1 p. m. This makes it possible to follow the successive changes with great ease. There is a conversion scale from millimeter to millibar on the margin of the map. The use of millimeter units at one end of each isobar and of millibar at the other is made in the hope that the public will come to accept the more convenient millibar.—*E. E. K.*

OBSERVATIONS OF POLARIZATION AND SOLAR RADIATION ON MONT BLANC.

By A. BOUTARIC.

[Abstracted from *Comptes Rendus*, January 30, 1922, pp. 309-310.]

Observations made on August 1, 2, 4, and 6, 1921, from 7 o'clock to 18:45 o'clock (true solar time), at Mont Blanc, permit the author to make certain generalizations:

(1) The mean values of solar radiation (observations made with an Ångström pyrheliometer) are about the same as those observed by Vallot.

(2) While the Mont Blanc atmosphere is exceptionally clear, the observed polarization is not very great. This did not exceed 0.68 (observations made with a Cornu photopolarimeter) while Cornu, on a plain, observed as high as 0.80. The author believes this disagreement is to be attributed to the diffusion of light by the snow; the snow diffuses the light in all directions and this is added to the radiation from the sky, with a consequent diminution, of polarized light.

(3) The polarization was less intense on August 1 than on the 6th, while the sky was more transparent (as shown by solar radiation intensity), but on the former date there was a layer of highly reflecting clouds over the valley below the station. A similar effect was noted on the morning of the 4th of August.—*C. L. M.*

THE DROUGHT OF 1921 IN THE BRITISH ISLES.

By C. E. P. BROOKS AND J. GLASSPOOLE.

[Reprinted from *Nature*, London, February 23, 1922.]

The general rainfall in England and Wales was the least in 1921, so far as can be ascertained, since 1788. Individual long records indicated that over a considerable part of the southeast of England 1921 was the driest year for at least a century and a half.

The months of 1921 were not individually so remarkable as was shown by a comparison with the driest month known to have occurred in the British Isles generally. As shown by a map of standard deviation of annual rainfall 1881-1915, for the British Isles, the least fluctuations of annual rainfall occurred along the coast in the northwest, increasing to a maximum in the southeast and center of the land masses. Constructing charts showing the distribution of barometric pressure over the globe during and preceding each of the great droughts, beginning with 1864, it is found that the conditions which commonly prevail during dry spells are high pressure over the British Isles, the greatest deviation from normal being usually over southeast England; low pressure over the Arctic regions, especially near Spitzbergen; and, generally, low pressure near the Tropics. The first factor is related to the 11-year sun-spot cycle, occurring most frequently two years after the sun-spot minimum and three or four years after sun-spot maximum, so that it tends to recur every five or six years. Great droughts occur only when both of these factors are favorable. With pressure low over the Arctic, two or three months warning of a drought would be given by the development of high pressure over northern Russia.

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SOLAR OBSERVATIONS.

SOLAR AND SKY RADIATION MEASUREMENTS DURING FEBRUARY, 1922.

By HERBERT H. KIMBALL, Meteorologist.

For a description of instruments and exposures, and an account of the method of obtaining and reducing the measurements, the reader is referred to this REVIEW for April, 1920, 48:225.

From Table 1 it is seen that direct solar-radiation intensities averaged close to normal values for February at Washington, D. C., and Lincoln, Nebr., and slightly below normal at Madison, Wis. But few measurements were obtained at Santa Fe, N. Mex., on account of the frequency of local smoke in the atmosphere.

Table 2 shows that the total solar and sky radiation received on a horizontal surface averaged close to the February normal at both Washington and Madison.

Skylight polarization measurements made on two days at Washington give a mean of 55 per cent, with a maximum of 57 per cent on the 24th. These are slightly below the average February Washington values. At Madison no measurements were obtained, as the ground was covered with snow during the entire month.

TABLE 1.—*Solar radiation intensities during February, 1922.*

[Gram-calories per minute per square centimeter of normal surface.]

Washington, D. C.

	Sun's zenith distance.										
	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon.
Date.	75th meridian time.	Air mass. A. M.					P. M.				Local mean solar time.
	e.	5.0	4.0	3.0	2.0	*1.0	2.0	3.0	4.0	5.0	e.
	mm.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	mm.
Feb. 3	2.16					1.51	1.34	1.20	1.05	0.93	2.16
4	2.36	0.80	0.94	1.12	1.29						2.62
6	5.16						1.24	1.12	.92	.76	5.79
8	1.52				1.20		1.12				1.68
11	5.36							.78	.63		6.02
14	1.60				.99						1.78
16	1.45						1.24	1.14			1.45
17	.86		1.15	1.29	1.43	1.60					.91
23	8.48		.68	.80	1.04						10.59
24	2.74		.94	1.07	1.26		1.18				2.49
25	2.74		.64	.77	.87						2.74
Means		(.80)	.87	1.01	1.15		1.22	1.06	.87	(.84)	
Departures		+.02	+.03	±.00	−.05		+.01	+.05	+.02	+.08	

* Extrapolated.

TABLE 1.—*Solar radiation intensities during February, 1922*—Con.

Madison, Wis.

	Sun's zenith distance.										
	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon.
Date.	75th meridian time.	Air mass. A. M.					P. M.				Local mean solar time.
	e.	5.0	4.0	3.0	2.0	*1.0	2.0	3.0	4.0	5.0	e.
	mm.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	mm.
Feb. 4	1.52		0.98	1.14	1.16						2.87
7	1.52	0.89	.99								1.88
9	3.30				1.16						3.81
11	1.19			1.25							1.45
13	.64		1.13	1.28	1.43		1.40	1.21			.86
14	1.02				1.25		1.27	1.03			1.78
15	.96						1.47				.96
16	.56	1.05	1.16	1.26	1.44	1.64					.74
24	1.12		1.09	1.22	1.35	1.56					1.68
27	2.16			1.21	1.41	1.61	1.32				1.52
28	.71			1.24	1.40	1.58	1.30	1.21			.96
Means		(.97)	1.07	1.23	1.32		1.35	1.15			
Departures		+.04	−.06	−.01	−.05		−.03	−.05			

Lincoln, Nebr.

Feb. 1	2.36		1.04	1.18	1.40	1.62					1.96
2	1.45	1.08	1.17	1.29	1.46	1.65	1.45	1.22	1.11	1.01	1.96
3	1.52	.74	.97	1.13	1.31			1.20	1.14	1.05	2.62
6	1.32		1.13	1.25	1.37	1.51	1.45	1.31	1.19	1.05	1.96
7	1.37	.98	1.07	1.18	1.39		1.36				1.96
10	3.81		.91	1.08	1.39	1.62	1.37	1.16	.98		4.75
11	1.32	.77	.91	1.18	1.33						1.68
13	.79				1.35						.86
14	.91						1.30	.88	.62	.62	2.06
15	1.52	1.00	1.15	1.28	1.44	1.61		1.28	1.15	1.03	1.37
16	1.37			1.12							1.96
18	2.74		.93	1.08	1.28						5.79
19	4.57			1.28	1.42						3.45
Means		.91	1.03	1.19	1.38		1.39	1.18	1.03	.95	
Departures		−.07	−.02	−.02	−.02		+.03	−.01	−.01	+.03	

Santa Fe, N. Mex.

Feb. 13	1.96			1.24	1.46	1.72					2.87
14	3.00								1.41	1.30	1.96
20	2.62			1.21	1.39						2.16
Means				(1.22)	(1.42)				(1.41)	(1.30)	
Departures				−.09	−.05				+.18	+.15	

* Extrapolated.

TABLE 2.—*Solar and sky radiation received on a horizontal surface.*

Week beginning.	Average daily radiation.			Average daily departure for the week.			Excess or deficiency since first of year.		
	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.
	cal.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
Jan. 29....	262	179	....	+55	−26	....	+ 67	+324	....
Feb. 5.....	186	250	....	−40	+38	....	−214	+590	....
12....	218	270	....	−29	+29	....	−420	+790	....
19....	303	207	....	+36	−55	....	−170	+405	....

MEASUREMENTS OF THE SOLAR CONSTANT OF RADIATION AT CALAMA, CHILE.

By C. G. ABBOT, Assistant Secretary.

[Smithsonian Institution, Washington, April 3, 1922.]

In continuation of preceding publications, the following table contains the results for the solar constant of radiation obtained at Montezuma, near Calama, Chile, in January, 1922. The values of $\rho/\rho sc$ are given in air mass 2, or, if not, the air mass is stated. The reader is referred for further statements regarding the arrangement and meaning of the table to the REVIEW for February, August, and September, 1919.

The observers report that during an observation about the middle of January, in a very high gust of wind, the diaphragm, which restricted the observation of the pyranometer to a definite region of sky around the sun, was blown away, and though searched for it could not be found anywhere on the mountain. The new pyranometer, referred to in this REVIEW for December, had not been compared with the old one as much as was thought desirable, and pending orders from Washington the observers reverted entirely to the long method of observation during the remainder of January, February and a part of March.

The observers call attention to the very high excellence of many of the long-method observations taken in January. This is in line with the statements of the writer in the article above cited.

The reader may note that from about the 8th of December there was a rapid fall of the solar-constant values, but that unfortunately from December 14 to January 8 ensued a period of very cloudy weather during which observations could not be taken. From January 8 there was a correspondingly rapid rise of solar-constant values. In general, the months of December and January, however, differed little from the mean of several years at the Chilean station, and have not, like the months of December and January of 1920 and 1921 been remarkable for exceptionally high values.

Date.	Solar constant.	Method.	Grade.	Transmission coefficient at 0.5 micron.	Humidity. $\rho/\rho sc$.	Humidity. V. P.	Humidity. Rel. hum.	Remarks.
1922. A. M.	*cal.*					*cm.*	*Per cent.*	
Jan. 8.....	1.923	M_1......	S−	0.859	[1] 0.488	0.40	21	Cirri scattered about sky.
P. M. 11....	1.903	$M_{1.75}$....	U	.852	[2] .470	.53	38	Clouds scattered about sky.
	1.947	$M_{1.59}$....	......	......	......	......	......	
	1.932	W. M....	......	......	......	......	......	
12....	1.904	M_2......	S−	.857	.502	.42	21	Cumuli in east and west.
	1.937	$M_{1.5}$....	......	......	......	......	......	
	1.922	W.M....	......	......	......	......	......	
13....	1.947	$M_{1.85}$....	S−	.857	[3] .534	.38	19	Clouds in east and west.
	1.937	$M_{1.56}$....	......	......	......	......	......	
	1.942	W. M....	......	......	......	......	......	
A. M. 14....	1.892	$M_{1.84}$....	S−	.857	[4] .507	.45	30	Clouds scattered about sky.
	1.957	$M_{1.5}$....	......	......	......	......	......	
	1.941	$M_{1.30}$....	......	......	......	......	......	
	1.941	W. M....	......	......	......	......	......	
15....	1.950	M_2......	S	.861	.556	.60	49	Cirri in north, cumuli in south.
	1.962	$M_{1.68}$....	......	......	......	......	......	
	1.945	$M_{1.5}$....	......	......	......	......	......	
	1.952	W. M....	......	......	......	......	......	
16...	1.969	$M_{1.83}$....	S	.866	[5] .638	.25	22	Some cirri in north.
	1.971	$M_{1.63}$....	......	......	......	......	......	
	1.970	W. M....	......	......	......	......	......	
17...	1.951	$M_{2.32}$....	S	.868	.609	.32	24	Cloudless.
	1.951	M_2......	......	......	......	......	......	
	1.947	$M_{1.5}$....	......	......	......	......	......	
	1.949	W. M....	......	......	......	......	......	
P. M. 19...	1.958	$M_{1.75}$....	S−	.870	[6] .653	.27	12	Do.
20...	1.936	E_0......	VG+	.861	[7] .568	.21	11	Do.
A. M. 21...	1.959	E_0......	E	.857	.662	.18	16	Do.
22...	1.941	E_0......	E+	.859	[8] .490	.27	26	Do.
24...	1.957	E_0......	E	.855	.468	.38	35	Do.
P. M. 25...	1.927	E_0......	E	.846	.414	.46	22	Clouds over high peaks.
A. M. 26...	1.936	E_0......	E+	.856	.454	.46	38	Cloudless.
P. M. 27...	1.944	E_0......	E	.844	.536	.46	24	Clouds over high peaks.
A. M. 28...	1.951	E_0......	E	.852	[9] .462	.51	53	Cloudless.
P. M. 30...	1.987	E_0......	E+	.837	.520	.42	23	Clouds scattered about sky.
A. M. 31...	1.959	E_0......	E^2	.851	.492	.54	40	Cirri in north and east.

[1] Air mass 1.00.
[2] Air mass 1.79.
[3] Air mass 1.84.
[4] Air mass 1.85.
[5] Air mass 1.84.
[6] Air mass 1.75
[7] Air mass 2.30.
[8] Air mass 2.49.
[9] Air mass 2.28.

WEATHER OF NORTH AMERICAN AND ADJACENT OCEANS.

NORTH ATLANTIC OCEAN.

By F. A. YOUNG.

The average pressure for February, 1922, was somewhat above the normal at land stations in Canada, the Azores, and Bermudas; below in the British Isles, while on the coast of the United States and in the West Indies the departures were slight.

Few fog reports were received from vessels, and it was observed at land stations in Great Britain on a few days in the first decade of the month.

Gales were unusually prevalent, especially over the mid section of the steamer lanes. In the 5° square between latitude 45° and 50° N. and longitude 35° and 40° W. winds of gale force were reported at the Greenwich mean noon observation on 16 days, a percentage of 57, while the normal for that square, as shown on the Pilot Chart, is 29 per cent.

Charts IX, X, and XI show the conditions on the 1st, 2d, and 3d, respectively, when a well-developed LOW covering an extensive area moved rapidly eastward, while there was also a second disturbance south of Newfoundland on the 3d. Storm logs follow:

American S. S. *Santa Rosalia:*

Gale began January 30, wind SE., 8. Lowest barometer 28.75 inches at 7 p. m. on the 1st, wind SW., 11, in latitude 47° 15′ N. longitude 29° 15′ W. End on the 2d, wind W. Highest force of wind 11, SW.; shifts SE.-SSE.-S.-SW.-W.

American S. S. *Satartia:*

Gale began January 31, wind SSE. Lowest barometer 28.65 inches at 7 a. m. on the 1st, wind SW., in latitude 42° 44′ N., longitude 36° 36′ W. End on the 2d, wind NW. Highest force of wind 12, SW.; steady from SW.

British S. S. *Albania:*

Gale began on the 2d, wind SSW. Lowest barometer 29.06 inches at noon on the 2d, wind N., 10, in latitude 50° 36′ N., longitude 16° 30′ W. End on the 3d, wind NW. Highest force of wind 10, W.; shifts W.-WNW.

American S. S. *Western Plains:*

Gale began on the 3d, wind SW. Lowest barometer 29.51 inches at 8 a. m. on the 3d, wind SW. 8, in latitude 40° 38′ N., longitude 57° 50′ W. End on the 4th, wind NW. Highest force of wind 8; shifts SW.-W.-NW.

On the 4th heavy weather still prevailed over a large portion of the ocean and along the shores of the British Isles, while on the 5th and 6th the storm area was restricted to the region west of the fortieth meridian. Storm logs follow:

Dutch S. S. *Veendijk:*

Gale began on the 4th, wind W. Lowest barometer 29.71 inches at 4 a. m. on the 5th, wind W., 9, in latitude 36° 05′ N., longitude 12° 36′ W. End on the 5th, wind SSE. Highest force of wind 9, W.; shifts W.-NW.-N.-NE.-E.-SSE.

American S. S. *Oregonian:*

Gale began on the 6th, wind S. Lowest barometer 29.42 inches at 4 a. m. on the 7th, wind S., 7, in latitude 48° 47′ N., longitude 18° 25′ W. End on the 7th, wind NW. Highest force of wind 9; shifts S.-NNW.

Charts XII, XIII, and XIV represent the conditions on the 7th, 8th, and 9th, respectively. On the 7th a strong "norther" prevailed in the Gulf of Mexico, accompanied by comparatively high barometric readings, as shown by the following storm log:

American S. S. *Gulfqueen:*

Gale began on the 6th, wind SW. Lowest barometer 29.84 inches at 10 a. m. on the 6th, wind N., 8, in latitude 25° 50′ N., longitude 96° 10′ W. End on the 7th, wind N. Highest force of wind 8, N.; shifts NE.-N.

On the 7th moderate westerly and southwesterly gales occurred off the American coast between Hatteras and Charleston, and there was also a LOW over Newfoundland, with a limited storm area between the fortieth and forty-fifth parallels and the fortieth and sixtieth meridians. Storm log:

British S. S. *Mercian:*

Gale began on the 7th, wind SSE. Lowest barometer 28.70 inches at 4 p. m. on the 8th, wind SW., 10, in latitude 43° 51′ N., longitude 53° 25′ W. End on the 8th, wind W. Highest force of wind 10, SW.; shifts S.-SW.-W.

On the 8th winds of gale force were prevalent over the greater part of the ocean west of the twentieth meridian, while by the 9th the most severe weather occurred between the fortieth and sixtieth meridians. Storm logs:

American S. S. *Oklahoma City:*

Gale began on the 7th, wind SW. Lowest barometer 29.17 inches at 11 p. m. on the 7th, wind SW., 12, in latitude 37° 40′ N., longitude 62° 20′ W. End on the 9th, wind NNW. Highest force of wind 12, SW.; shifts SW.-NW.

Norwegian S. S. *Foldenfjord:*

Gale began on the 8th, wind S. Lowest barometer 29.13 inches at midnight on the 8th, wind SW., 11, in latitude 47° 30′ N., longitude 42° 15′ W. End on the 10th, wind NNW. Highest force of wind 12, SW.; shifts S.-SW.-W.-NW.-NNW.

From the 10th to the 15th conditions did not change materially, as during that period portions of the steamer lanes were swept by moderate to strong gales. Storm logs:

American S. S. *W. H. Tilford:*

Gale began on the 11th, wind WSW. Lowest barometer 30 inches at 4 a. m. on the 11th, wind WSW., in latitude 38° 12′ N., longitude 53° 25′ W. End on the 14th, wind SW. Highest force of wind 11, SW.; shifts SSW.-W.

British S. S. *Winnebago:*

Gale began on the 11th, wind S. Lowest barometer 30.09 inches at midnight on the 12th, wind SSW., 9, in latitude 74° 45′ N., longitude 38° 50′ W. End on the 13th, wind SW. Highest force of wind 9, SSW.; shifts SSW.-SW.

Norwegian S. S. *Rannenfjord:*

Gale began on the 14th, wind W. Lowest barometer 29.84 inches at 8.16 a. m. on the 14th, wind W., 10, in latitude 45° 08′ N., longitude 50° 55′ W. End on the 14th, wind W. Highest force of wind 11; steady from the west.

On the 15th the second "norther" of the month appeared in the western part of the Gulf of Mexico, and winds of from 40 to 65 miles an hour were reported from a limited territory in the vicinity of New Orleans and Galveston.

Charts XV and XVI represent the conditions on the 16th and 17th where heavy weather prevailed over various portions of the ocean. Storm logs.

American S. S. *Wm. G. Warden:*

Gale began on the 16th, wind WNW. Lowest barometer 29.87 inches at 2 p. m. on the 16th, wind WNW., 7, in latitude 24° 56′ N., longitude 80° 25′ W. End on the 17th, wind NE. Highest force of wind 9; shifts SSW.-NW.

Danish S. S. *United States:*

Gale began on the 15th, wind WSW. Lowest barometer 29.06 inches at 2 p. m. on the 15th, wind WSW., 9, in latitude 58° 03′ N., longitude 18° 30′ W. End on the 17th, wind W. Highest force of wind 9, WSW.; steady WSW.

British S. S. *River Orontes:*

Gale began on the 17th, wind S. Lowest barometer 30.02 inches at 1.30 p. m. on the 17th, wind S., in latitude 34° 57′ N., longitude 53° 08′ W. End on the 17th, wind W. Highest force of wind 10; shifts WSW.-W.

During the remainder of the month the ocean north of the fortieth parallel was swept by one disturbance after the other, with hardly any interval between the storms. On the 22d all of the 16 reporting vessels between the fiftieth meridian and the European coast, north of the fortieth parallel, encountered gales of from 40 to 65 miles an hour, with hail and snow in the western section. On the 23d the most severe weather occurred between the thirtieth and fiftieth meridians, and from that date until the end of the month southerly gales also prevailed off the coast of Europe. Storm logs.

American S. S. *Potomac:*

Gale began on the 18th, wind SW. Lowest barometer 29.48 inches at 2 a. m. on the 21st, wind NW., 9, in latitude 49° 48′ N., longitude 19° 50′ W. End on the 21st, wind WSW. Highest force of wind 9, NW.; shifts NW.-W.

British S. S. *Kenbane Head:*

Gale began on the 18th, wind SW. Lowest barometer 29.12 inches at 12.17 a. m. on the 19th, wind WSW., 9, at latitude 52° 36′ N., longitude 22° W. End on the 20th, wind S. Highest force of wind 12, in squalls; shifts SW.-WSW.

U. S. Coast Guard S. S. *Seneca:*

Gale began on the 20th, wind W. Lowest barometer 29.80 inches at noon on the 22d, wind NW., in latitude 44° 49′ N., longitude 48° 20′ W. End on the 24th, wind NW. Highest force of wind 11, NW.; steady from NW.

American S. S. *Carplaka:*

Gale began on the 21st, wind WSW. Lowest barometer 29.74 inches at 8 a. m. on the 23d, wind W., in latitude 39° 56′ N., longitude 39° 40′ W. End on the 25th, wind WSW. Highest force of wind 10, W.; steady from west.

American S. S. *City of Freeport:*

Gale began on the 24th, wind SSW. Lowest barometer 29.57 inches at 1 p. m. on the 25th, wind SSW., 9, in latitude 51° 10′ N., longitude 8° 15′ W. End on the 25th, wind W. Highest force of wind 9, SSW.; shifts SSW.-W.

British S. S. *Vasconia:*

Gale began on the 24th, wind SW. Lowest barometer 28.86 inches at 3 a. m. on the 25th, wind W. 11, in latitude 46° 23′ N., longitude 32° 55′ W. End on the 26th, wind W. Highest force of wind 11; shifts SW.-SW. by S.

Swedish S. S. *Stockholm:*

Gale began on the 24th, wind SSW. Lowest barometer 28.78 inches at 11 p. m. on the 24th, wind SSW., in latitude 57 N., longitude 19° 25′ W. End on the 25th, wind WSW. Highest force of wind 9; shifts SSW.-SW.-WSW.

British S. S. *Clan Malcolm:*

Gale began on the 26th, wind SW. Lowest barometer 29.45 inches at 4 a. m. on the 28th, wind SW., in latitude 52° 15′ N., longitude 5° 23′ W. End on the 28th, wind W. Highest force of wind 10, SW.; shifts SSW.-W.

British S. S. *Alpine Range:*

Gale began on the 25th, wind SSW. Lowest barometer 28.80 inches on the 28th, wind SW., 9. in latitude 56° 25′ N., longitude 14° 55′ W. End on the 28th, wind W. Highest force of wind 10; shifts WSW.—S.

NORTH PACIFIC OCEAN.

By F. G. Tingley.

Measured by the number of gales reported the weather on the North Pacific Ocean in February was nearly normal in character. The number of days on which gales were experienced was somewhat less than in 1920 and 1921 and slightly greater than in 1919. Pressure conditions over the more northerly portions of the ocean were abnormal, however. Beginning on the 1st the barometer rose rapidly at Dutch Harbor, where it had been uniformly low since the end of December, and by the afternoon of the 5th had reached a height of 30.84 inches, or about 1.26 inches above normal. Just a month before, on January 5, a barometer reading of 28.40 inches had been recorded at that place. Previous high pressures observed at Dutch Harbor are as follows: 30.94 inches on January 4, 1916, 30.86 inches, March 7, 1918, 30.74 inches, January 19, 1920.

At Honolulu and Midway Island pressure conditions were not specially marked, being approximately normal for the month at both places. On the 16th, when a depression moved northward immediately to the east of Midway Island, the barometer at that place fell to 29.34 inches, the lowest point reached during the month.

February opened with a well-defined anticyclone extending westward from the American coast and an energetic depression over Bering Sea. Vessels east of the Hawaiian Islands on the 1st to 3d were experiencing fresh to moderate notheast gales under conditions similar to those noted during the last week of January. On the 4th there were evidences of an anticyclone advancing eastward from Siberia and by the afternoon of the 5th abnormally high pressure was established over the Aleutians, Bering Sea, and northwestern Alaska. On the front of this area of high pressure a vigorous cyclone developed in the eastern Gulf of Alaska with strong to whole westerly gales prevailing over areas to the southward. On February 4, eastern time, in conjunction with the high pressure area just referred to and another one of somewhat less magnitude over Mongolia a deep depression formed to the eastward of Japan, having a central isobar of 28.98 inches. This depression moved northeastward to Bering Sea, where it dissipated during the 8th. Several reporting vessels on its eastern and southern sides, though at some distance from the center, experienced southerly to westerly gales, reaching force 11 in some cases. Typical storm logs are as follows:

American S. S. *Hoosier State*, Capt. Thomas Blau, Observer W. N. Calcutt, Yokohama (February 1) for Manila:

Gale began on 4th, wind SSE. Lowest barometer, 30.17 inches, occurred at 4 p. m., same date, in 34° N., 162° 58′ E., wind at time being SE., 9. Gale ended at 10 p. m. of 5th. No shifts in wind. Highest force, 9

American S. S. *Viniti*, Capt. G. Johnsen, Observer A. G. Graham, Dairen (January 28) for Portland:

Gale began on 3d, wind SSE. Lowest barometer, 29.10 inches, occurred at noon of 4th in 42° 50′ N., 154° 47′ E., wind remaining at SSE. Gale ended same day. Highest force, 11. Shifts, SSE., SSW.

During the period from the 7th to the 10th low pressure prevailed off the American coast, the anticyclone which had occupied the region toward the Hawaiian Islands having suddenly, on the 5th, advanced eastward over the continent. On its front strong northers prevailed in the Gulf of Mexico and Gulf of Tehuauntepec. The American S. S. *Newport*, Capt. G. McKinnon, Observer W. N. Prencel, felt the full force of this norther on the 7th when proceeding from Champerico to Salina Cruz.

Captain McKinnon has furnished the following detailed report:

[Position of vessel at beginning of gale, 15° 45′ N., 93° 45′ W., at end, 15° 15′ N., 95° 30′ W.]

Date.	Greenwich mean time.	Wind direction.	Wind force, Beaufort.	Barometer.	Thermometer.
	H. m.				°
Feb. 7	0 35	Northerly	4	30.03	83
	2 35	do	6	30.05	82
	4 35	do	8	30.14	80
	6 35	Westerly	8	30.15	81
	7 35	West-northwest	8	30.12	
	8 35	Northwest by west	10	30.09	75
	9 35	Northwest	10	30.09	
	10 35	Northerly	10	30.09	70
	12 35	do	10	30.09	72
	14 35	do	10	30.09	72
	16 35	North-northwest	10	30.11	76
	17 35	Northerly	8	30.11	
	18 35	Northeast	6	30.11	74

From 12 noon to 6 p. m., ship's time (6.35 to 12.35 G. M. T.), the *Newport* was about 2 miles from shore and at times the vessel was covered with fine sand. About 9 p. m. a heavy easterly swell commenced. Spoon drift was caused both to lee and windward. The sea throughout the gale was short and choppy.

According to press reports the American S. S. *Fairfield City* arrived at San Pedro from Panama on February 18 with three members of her crew injured and two lifeboats and the bridge wrecked as the result of an encounter with a hurricane while coming up the coast. The *Fairfield City* was reported at Panama about the 6th. No other circumstances are known.

Very heavy weather developed in connection with the depression referred to as being in the Gulf of Alaska on the 5th and appears to have continued into the period from the 7th to the 10th when low pressure prevailed off the American coast. The British S. S. *Bessie Dollar*, from Victoria (January 30) for Yokohama, had her bridge wrecked and sustained other damages during this period and was obliged to return to port.

On the 11th an anticyclone which had advanced from the mid Pacific was encroaching upon the California coast. This change to high pressure over the eastern portion of the ocean was but temporary, however. On the morning of the 12th a fresh depression was forming to the east of the Hawaiian Islands, with a northward movement. On the 14th it merged with another depression which had formed over the Gulf of Alaska and moved southward, the center of the combined depression being on the morning of the 14th near latitude 30° N., longitude 143° W. During the next several days it moved slowly northward, then eastward, dissipating off the British Columbia coast on the 18th. Strong gales were experienced by vessels to the southward and westward of the center. At 6 a. m. on the 16th the barometer on the S. S. *Viniti*, previously referred to, fell to 28.92 inches. This was in 48° 08′ N., 134° 18′ W. The wind at the time was south, later veering to southwest. Highest force, 10.

Following this depression, the North Pacific anticyclone became established between the Hawaiian Islands and the American mainland, while low pressure appeared over the Aleutians. With some unimportant modifications this general and normal distribution continued until the 27th when an extensive and vigorous depression advanced eastward and on the 28th covered the Gulf of Alaska and the ocean area to the southward. On the morning of the 28th the barometer at Kodiak registered 28.64 inches.

The following note regarding conditions in the Japan area from the 12th to the 18th is taken from the Weekly Weather Report for that period issued by the Imperial Marine Observatory at Kobe:

On the 12th several cyclone centers were lying on our east coast, causing a heavy rain storm in eastern Japan. The weather was mostly fine in western Japan, owing to the approach of an anticyclone from the continent. On the 13th a high area occupied Manchuria. The weather was mostly fine in the Far East.

On the 14th the high area was moving eastward while a depression was developing near Formosa, followed by another one from Luzon. On the 15th the high area occupied the Okhotsk Sea. Both depressions were approaching our south coast. Cloudy weather was prevailing in this country. Rain set in in southern Kinsin. On the 16th both depressions grew deeper and approached the Tokaido coast. A heavy rainstorm was prevailing there.

On the 17th one of the depressions traversed southeastern Japan and entered into the Pacific from the neighborhood of Cape Kinkasan, while the other one passed along our southeast coast. A heavy rainstorm prevailed in eastern Japan generally.

NOTES ON WEATHER IN OTHER PARTS OF THE WORLD.

Newfoundland.—ST. JOHN'S, February 1.—Strong easterly gales that have been raging for several days have blockaded St. John's Harbor with ice and no shipping can enter or leave the port until there is a change of wind.—*Washington Times, February 1, 1922.*

ST. JOHN'S, February 9.—Newfoundland is besieged again by snow and ice. A blizzard swept over the colony last night and to-day and blocked all traffic. * * *

The gale swept the ice fields back into St. John's Harbor and no ships could leave or enter.—*Worcester (Mass.), Telegram, February 10, 1922.*

North Atlantic.—BOSTON, February 2.—Warning of North Atlantic ice fields 7 miles wide and 135 miles long moving south, 215 miles east of Cape Race, was sent out to-day by the Hydrographic Office.—*Washington Times, February 2, 1922.*

Sweden and the Baltic.—STOCKHOLM, February 5.—Exceptional cold is being experienced in Sweden, especially in the northern part. Ports and harbors gradually are becoming blockaded with ice, the ferries from Trelleborg to Sassnitz, Prussia, have ceased, and connection with Denmark is maintained only with great difficulty.—*New York Tribune, February 6, 1922.*

REVAL, February 18.—The provisioning of starving Russia has become a task of battling with ice in the Baltic.—*Chicago Post, March 11, 1922.*

GOTHENBURG, February 26.—Further breaking up of the ice blockade at this port permitted the entrance of 14 more ice-bound ships Saturday. There is now open water between Copenhagen and Malmo.—*Washington Evening Star, February 27, 1922.*

Russia.—REVAL, February 18.—Petrograd has been icebound for several weeks, and a number of ships, mostly German freighters, have been caught by ice in the Finnish Gulf.—*Chicago Post, March 11, 1922.*

Germany.—BERLIN, February 5.—In a raging blizzard the inhabitants of the capital of Germany stood in the streets to-day pumping old wells and trying the frozen hydrants. Berlin is to-day without water, gas, electricity, street cars, or railroads, in the midst of one of the worst winters on record.—*Chicago Tribune, February 6, 1922.*

Hungary.—BUDAPEST, February 17.—Hungary is having the hardest winter within a generation which daily claims new victims. The Danube River, which is running high and is full of ice, reaped a heavy toll among

those along its banks and on the islands in the stream. Even crows, unable to survive the cold, can be seen everywhere clinging frozen to the bare trees.—*Brooklyn Daily Eagle, February 17, 1922.*

Italy.—ROME, February 9.—The cold wave which is the severest in years, accompanied by a considerable fall of snow, has forced a modification of the coronation ceremonies for Pope Pius XI, Sunday.—*New York Evening Mail, February 9, 1922.*

Samoa.—APIA, February 3.—The steamer *Suva* arrived at Suva after encountering a cyclonic storm early on Saturday.—*Samoa Times.*

DETAILS OF THE WEATHER IN THE UNITED STATES.

GENERAL CONDITIONS.

By A. J. HENRY.

Among the larger features of the month was the pronounced increase in the number and intensity of cyclonic storms which passed inland from the Pacific south of the mouth of the Columbia River. This movement in latitude was directly responsible for the increase in precipitation in California and perhaps in the Gulf and South Atlantic States. The mean temperature in Montana, the Dakotas, Wyoming, and Idaho was much below the seasonal normal, especially in Montana. East of the Mississippi, however, except for Wisconsin and a part of Minnesota, mean temperature was uniformly in excess of normal. The single event which stands out prominently in the month's weather was the fall of snow in the Plains States and the intense glaze storm in Wisconsin and Michigan during the last week of February.

CYCLONES AND ANTICYCLONES.

By W. P. DAY, Observer.

Low-pressure areas were mostly of Pacific origin and their tracks covered a wide range in latitude. The high-pressure areas, however, which were mostly of the Alberta type, came in rapid succession and generally confined themselves to a well-marked path. The number of HIGHS plotted was considerably above the normal.

Tables showing the number of HIGHS and LOWS by types follow:

Lows.	Alberta.	North Pacific.	South Pacific.	Northern Rocky Mountain.	Colorado.	Texas.	East Gulf.	South Atlantic.	Central.	Total.
February, 1922	2.0	6.0	2.0	......	1.0	3.0	......	2.0	......	16.0
Average number 1892–1912, inclusive	3.1	2.3	1.0	0.2	1.5	1.5	0.5	0.2	0.7	11.0

Highs.	North Pacific.	South Pacific.	Alberta.	Plateau and Rocky Mountain region.	Hudson Bay.	Total.
February, 1922	1.0	2.0	9.0	1.0	1.0	14.0
Average number, 1892–1912, inclusive	0.8	0.5	4.7	1.2	0.6	7.8

FREE-AIR CONDITIONS.

By W. R. GREGG, Meteorologist.

For the month as a whole free-air temperatures were below normal in the Northern States and above normal in the Southern States, thus conforming quite closely to mean values at the surface. The largest negative departures occurred at Ellendale, being most pronounced in the lower levels and becoming rather steady at about −2.5° C. above 1,500 meters. A similar though smaller decrease in departures in the upper levels was observed also at Drexel and Royal Center. The same tendency is apparent in the values at Broken Arrow and Groesbeck, where temperatures were above normal at all levels, but increasingly so as greater altitudes were reached. In other words, owing to some widespread influence, the temperature decrease with altitude in all parts of the country was considerably less than normal, and hence the upper levels were warm as compared with those near the surface. Indeed, at Ellendale, where there is normally in February a practically isothermal condition from the surface to 2,000 meters above sea level, there was during the present month a large inversion, the recovery of temperature not taking place until an altitude of 3,000 meters was reached. At all stations conditions were more nearly like those usually found in December and January than those found in February. The cause is not far to seek. A glance at Chart IV will show that there was a larger latitudinal temperature gradient than normally occurs—a condition that would produce relatively low free-air pressures in the North and relatively high in the South, with a resulting larger south component or (what amounts to the same thing) a smaller north component in the winds. That this is what actually occurred is indicated by the values given in Table 2. The departures from normal were small, but in nearly all cases they were in the same direction, sufficiently so to cause the temperature anomalies referred to.

In general the changes in free-air temperature from day to day were in the same sense as were those at the surface. There were some exceptions, however, mostly associated with anticyclones in the northwest. These areas of high pressure are usually accompanied by clear weather, and radiation is very active. Not infrequently, as the center passes a given point and the wind shifts from northerly to southerly, the surface temperature remains low or even continues to fall. This tendency exists only in the lowest layers, usually within 200 to 500 meters of the surface. At higher levels the response of temperature to the wind shift is immediate and decided. A case in point occurred on February 19 to 20, during which period a moderate anticyclone moved almost due east from eastern Montana to Minnesota. Generally clear weather prevailed. At both Ellendale and Drexel the wind at all levels was NW. and fairly strong, and temperatures were low as the anticyclone approached. When the crest of the latter passed these stations the wind became SE. to SW. and of moderate strength, and the temperature in the free air therefore increased, but that at the surface continued to fall. The rise in temperature at the upper levels was not large, the wind changing only from NW. and WNW. to WSW. When the wind shifts through a larger angle the changes in temperature likewise become greater. For example, from February 6 to 7 the free-air wind backed from N. and NNW. to SW., the temperature meanwhile increasing about 15° C. This is the type of change that occurs above the surface, even though the reverse change occurs for a time at the latter, owing to radiation or to peculiar local effects of topography, etc. In this connection it is of interest to recall that the temperature distribution in winter cyclones in the extreme Northwest—near the Pacific—is usually quite the reverse

of that found in these cyclones after they have reached the central and eastern States, i. e., NW. winds from the Pacific are warm and SE. winds from the continent are cold. Unfortunately no free-air observations have yet been made in this region, and it is therefore impossible to say what the temperature distribution above the surface is. However, it seems reasonable to assume that in front of the cyclone there is an inversion and behind it a lapse rate not greatly differing from normal, with the result that at some moderate height the temperature is higher in the southerly than in the northerly current. This assumption finds support in the case above cited, viz, that of February 19 to 20, when the southerly current in the rear of the anticyclone was cold at the surface but warm at higher levels.

The lowest free-air temperatures recorded during the month were −27° C. at an altitude of 4,500 meters at Drexel on the 5th and −28° C. at an altitude of 4,000 meters at Ellendale on the 27th.

Relative humidity was slightly above normal in the extreme North and South, and below at intermediate stations. The departures from normal were of about equal amount at all levels, except at Groesbeck, where there was an increasing plus departure with height. Vapor pressure at this station was also decidedly above normal. Elsewhere there was for the most part a moderate minus departure.

As already stated, resultant winds were from a more southerly point than usual. There was a fairly large plus departure in wind speeds at Groesbeck and Royal Center, but elsewhere little variation from the normal.

Unusually high winds were observed as follows:

[By means of kites.]

Station.	Date.	Direction.	Velocity.	Altitude.
			m. p. s.	*Meters.*
Due West, S. C	3	w	37	2,100
Groesbeck, Tex	9	wsw	38	1,400
Royal Center, Ind	8	sw	45	900
Do	11	w	35	3,800

[By means of pilot balloons.]

Station.	Date.	Direction.	Velocity.	Altitude.
Bolling Field, D. C	3	w	38	2,700
Broken Arrow, Okla	2	w	46	3,900
Do	3	w	50	5,700
Burlington, Vt	21	w	38	4,000
Do	25	w	35	5,000
Drexel, Nebr	13	wnw	38	5,100
Due West, S. C	2	w	47	4,400
Do	3	w	35	3,100
Do	3	wsw	45	3,500
Do	4	w	34	4,400
Ellendale, N. Dak	6	nnw	36	6,000
Do	15	nw	41	4,800
Do	16	nw	35	5,800
Do	20	w	35	6,400
Do	23	w	44	7,700
Groesbeck, Tex	6	wsw	35	3,000
Lansing, Mich	17	wsw	39	2,200
Madison, Wis	7	nnw	38	4,200
McCook Field, Ohio	13	w	39	4,100
Do	14	wsw	41	5,000
Do	24	w	34	4,200
Mitchell Field, N. Y	8	nw	42	2,700
Do	24	nw	66?	3,500
Royal Center, Ind	11	w	40	5,800
Do	14	w	38	5,200
San Francisco, Calif	11	wnw	36	4,100
Washington, D. C	2	wsw	39	3,200
Do	3	w	44	2,700
Do	14	w	34	5,000
Do	25	w	39	2,400

Free-air winds at altitudes of 2,000 meters or more were for the most part from a westerly direction. There were no exceptions in the northeastern part of the country as far south as North Carolina and as far west as Indiana. In the Southeastern States easterly winds were general up to 3 or 4 kilometers on the 21st when high pressure prevailed over the lower Lakes and a vigorous cyclone was advancing from the Southern Plains States. These easterly winds were, however, exceedingly light and veered to SSW. with the eastward movement of the cyclone. In southern Florida easterly winds prevailed from the 18th to 24th, but extended only to 3 or 4 kilometers.

A very exceptional case of free-air easterly winds occurred at Ellendale, N. Dak., on the morning of the 28th. The wind at the surface was SW.; from 250 to 2,000 meters it was NW.; and *above* 2,000 meters an easterly wind prevailed up to 5,000 meters, the highest point reached. The afternoon observation showed a similar condition, with some slight changes. A SW. wind still prevailed at the surface; above it in succession were found WNW. winds up to 1,500 meters; SE. from 2,000 to 4,000 meters; and SW. from 4,500 to 7,000 meters. In all cases the winds were light, the lowest velocity, 1 meter per second, being observed in a layer about 1 kilometer thick where the change from a westerly to an easterly component in the winds occurred, and the highest, 8 meters per second, just above the layer of SE. winds in the afternoon.

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressures during February, 1922.*

TEMPERATURE (°*C.*).

Altitude. M. S. L. (*m.*)	Broken Arrow, Okla. (233*m.*)		Drexel, Nebr. (396*m.*)		Due West, S. C. (217*m.*)		Ellendale, N. Dak. (444*m.*)		Groesbeck, Tex. (141*m.*)		Royal Center, Ind. (225*m.*)	
	Mean.	Departure from normal.	Mean.	Departure from normal.	Mean.	Departure from normal.	Mean.	Departure from normal.	Mean.	Departure from normal.	Mean.	Departure from normal.
Surface	5.6	+0.2	−5.9	−2.1	10.7		−16.6	−7.7	11.7	+1.9	−1.7	−0.5
250	5.5	+.2			10.5				11.2	+1.8	−1.9	−.5
500	4.3	+.6	−6.5	−2.3	9.2		−16.3	−7.2	10.0	+1.7	−3.6	−.4
750	3.3	+.7	−7.4	−2.9	8.2		−14.6	−5.8	10.0	+2.2	−4.1	
1,000	3.2	+1.1	−6.5	−2.6	7.4		−12.9	−4.3	9.9	+2.4	−4.8	−.3
1,250	3.5	+1.8	−5.0	−1.6	6.4		−11.8	−3.7	9.4	+2.5	−5.7	−.7
1,500	3.0	+2.1	−4.5	−.9	5.5		−11.2	−3.2	8.8	+2.6	−6.2	−.7
2,000	2.1	+2.7	−5.7	−1.1	3.7		−12.0	−2.7	7.0	+2.8	−7.2	−.5
2,500	.0	+3.1	−7.7	−.9	1.2		−13.6	−2.2	5.5	+3.8	−8.0	+.4
3,000	−2.8	+2.8	−10.2	−.7	−.9		−16.4	−2.5	3.3	+4.1	−10.4	+.2
3,500	−5.8	+2.4	−13.0	−.8	−2.1		−18.9	−2.2	.3	+2.9	−13.2	+.1
4,000	−8.9		−15.8	−.3			−21.5	−2.3	−2.6	+2.6	−16.3	−.4
4,500			−18.5	+.2								

RELATIVE HUMIDITY (%).

Altitude. M. S. L. (*m.*)	Broken Arrow, Mean.	Departure from normal.	Drexel, Mean.	Departure from normal.	Due West, Mean.	Departure from normal.	Ellendale, Mean.	Departure from normal.	Groesbeck, Mean.	Departure from normal.	Royal Center, Mean.	Departure from normal.
Surface	63	−6	74	−4	75		87	+8	75	+1	73	−4
250	63	−5			75				73	+1	73	−4
500	63	−4	73	−3	72		85	+7	70	+1	72	−5
750	60	−4	71	−1	70		77	+3	66	+1	70	−4
1,000	56	−2	65	−2	69		72	+1	61	+1	66	−4
1,250	52	−2	60	−3	68		69	+2	58	+2	62	−4
1,500	50	−2	56	−3	66		67	+4	56	+5	58	−4
2,000	44	−8	51	−3	61		66	+5	51	+5	52	−4
2,500	42	−11	50	−2	64		66	+5	47	+5	51	−3
3,000	40	−9	51	−2	58		65	+5	47	+8	53	−1
3,500	38	−9	53	0	54		66	+7	49	+16	54	−1
4,000	36		50	−1			64	+5	50	+22	53	−1
4,500			47	−5								

VAPOR PRESSURE (*mb.*).

Altitude. M. S. L. (*m.*)	Broken Arrow, Mean.	Departure from normal.	Drexel, Mean.	Departure from normal.	Due West, Mean.	Departure from normal.	Ellendale, Mean.	Departure from normal.	Groesbeck, Mean.	Departure from normal.	Royal Center, Mean.	Departure from normal.
Surface	6.18	−0.21	3.01	−0.90	10.34		1.45	−1.29	11.13	+1.90	4.14	−0.43
250	6.14	−.20			10.20				10.57	+1.79	4.08	−.42
500	5.66	+.10	2.83	−.89	9.17		1.44	−1.27	9.39	+1.55	3.64	−.30
750	5.00	+.13	2.54	−.82	8.65		1.48	−1.07	8.57	+1.43	3.25	−.32
1,000	4.50	+.23	2.51	−.64	8.12		1.63	−.81	7.60	+1.23	2.97	−.34
1,250	4.11	+.32	2.50	−.47	7.39		1.78	−.54	6.95	+1.30	2.53	−.46
1,500	3.75	+.36	2.41	−.31	6.82		1.78	−.39	6.43	+1.65	2.19	−.48
2,000	2.91	+.03	2.05	−.20	5.29		1.61	−.24	5.20	+1.61	1.71	−.46
2,500	2.44	−.08	1.75	−.09	4.52		1.41	−.14	4.43	+1.68	1.55	−.26
3,000	2.00	−.08	1.48	−.03	3.50		1.14	−.06	3.94	+1.74	1.25	−.25
3,500	1.53	−.24	1.17	−.03	3.34		.97	+.07	3.49	+1.75	.83	−.39
4,000	1.11		.84	−.06			.90	+.18	3.17	+2.09	.51	−.51
4,500			.61	−.15								

TABLE 2.—*Free-air Resultant Winds (m. p. s.) during February, 1922.*

Altitude. M. S. L. m.	Broken Arrow, Okla. (233m.)				Drexel, Nebr. (396m.)				Due West, S. C. (217m.)		Ellendale, N. Dak. (444m.)				Groesbeck, Tex. (141m.)				Royal Center, Ind. (225m.)			
	Mean.		Normal.		Mean.		Normal.		Mean.		Mean.		Normal.		Mean.		Normal.		Mean.		Normal.	
	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.
Surface	N. 22°E.	1.1	S. 87°W.	0.9	N. 68°W.	2.2	N. 65°W.	1.4	S. 71°W.	1.4	N. 43°W.	5.0	N. 37°W.	2.9	S. 28°W.	1.2	N. 50°W.	0.5	S. 63°W.	2.3	S. 88°W.	2.1
250	N. 24°E.	1.0	S. 69°W.	1.0	...	...	...	...	S. 78°W.	1.6	...	...	...	...	S. 24°W.	1.8	N. 68°W.	0.6	S. 68°W.	3.4	S. 83°W.	2.1
500	S. 10°E.	.4	S. 80°W.	1.2	N. 71°W.	3.0	N. 73°W.	2.0	S. 86°W.	3.8	N. 44°W.	5.3	N. 42°W.	3.1	S. 39°W.	2.8	S. 58°W.	1.2	S. 52°W.	4.9	S. 67°W.	3.3
750	S. 5°E.	1.2	S. 62°W.	2.8	N. 80°W.	4.0	N. 71°W.	4.0	S. 85°W.	5.6	N. 47°W.	5.6	N. 50°W.	4.4	S. 36°W.	3.2	S. 58°W.	2.2	S. 65°W.	7.3	S. 64°W.	4.5
1,000	S. 52°W.	1.8	S. 60°W.	4.0	N. 82°W.	5.1	N. 68°W.	5.4	S. 80°W.	7.5	N. 52°W.	6.0	N. 48°W.	5.2	S. 53°W.	4.1	S. 70°W.	3.4	S. 65°W.	9.3	S. 74°W.	5.2
1,250	N. 87°W.	3.0	S. 82°W.	4.5	N. 84°W.	6.9	N. 66°W.	6.6	S. 80°W.	10.2	N. 56°W.	5.9	N. 50°W.	6.4	S. 70°W.	6.9	S. 80°W.	4.3	S. 75°W.	10.1	S. 80°W.	6.9
1,500	N. 86°W.	3.6	S. 87°W.	5.1	N. 78°W.	9.1	N. 67°W.	8.5	S. 76°W.	11.3	N. 62°W.	6.7	N. 58°W.	7.9	S. 74°W.	8.1	S. 88°W.	5.6	S. 81°W.	12.8	S. 81°W.	8.0
2,000	S. 85°W.	6.3	N. 72°W.	7.4	N. 76°W.	11.2	N. 69°W.	10.5	S. 78°W.	14.0	N. 71°W.	9.3	N. 64°W.	9.8	S. 73°W.	11.1	N. 86°W.	7.7	S. 88°W.	15.0	S. 85°W.	9.3
2,500	N. 81°W.	8.1	N. 57°W.	6.1	N. 77°W.	13.2	N. 70°W.	12.4	S. 81°W.	16.1	N. 74°W.	11.4	N. 68°W.	12.4	S. 80°W.	12.0	N. 84°W.	9.2	N. 88°W.	16.8	S. 87°W.	11.7
3,000	S. 88°W.	11.9	N. 77°W.	9.6	N. 84°W.	15.7	N. 73°W.	14.6	S. 84°W.	18.5	N. 83°W.	13.0	N. 70°W.	13.5	S. 79°W.	13.3	W.	11.6	N. 87°W.	20.8	S. 84°W.	12.5
3,500	N. 87°W.	12.4	N. 58°W.	15.0	N. 88°W.	18.2	N. 71°W.	16.0	W.	16.2	N. 78°W.	15.0	N. 72°W.	12.2	S. 54°W.	14.7	N. 82°W.	14.1	N. 84°W.	23.6	S. 89°W.	16.3
4,000	N. 82°W.	9.0	...	...	S. 87°W.	18.7	N. 77°W.	15.9	...	...	N. 73°W.	14.9	N. 68°W.	12.7	S. 68°W.	20.5	N. 67°W.	12.9	N. 70°W.	23.2	S. 82°W.	17.9
4,500	N. 45°W.	16.5	...	...	N. 80°W.	18.0	N. 81°W.	18.5	...	...	W.	16.4	N. 64°W.	13.7	...	...	N. 77°W.	14.8	N. 67°W.	19.5	...	...
5,000	...	...	...	...	S. 68°W.	18.5	N. 76°W.	19.7	...	...	...	...	S. 67°W.	18.4	...	...	...	...	...	...	...	...

A condition like this one is occasionally, not frequently, observed in summer, when pressure and temperature gradients are weak over extended areas. In this case, however, an anticyclone of great vigor was central a short distance southwest of Ellendale. This position was favorable for the NW. winds that were found in the lower levels. But why the SE. winds above them? Unfortunately only a short kite flight was possible because of light winds. The record showed, however, a marked temperature inversion. On the other hand, there was a fall in temperature with height above Drexel, with the result that, although at the surface the temperature decreased northward, in the free air it decreased southward, thus reversing the normal poleward pressure gradient and consequently producing easterly instead of westerly winds. These easterly winds were general over a considerable portion of the country on this day, but in other places extended down to the surface instead of being underrun by westerly winds. At Drexel, farther removed from the anticyclonic center, ENE. winds were general up to 3,000 meters; above this height there was a sudden shift to WSW.—a direction nearly parallel to the surface isotherms. In this region the poleward temperature gradient was much steeper than it was farther north. NE. winds were observed also at Madison and Broken Arrow up to 2,000 meters; at Camp Lewis, Washington State, up to 4,500 meters; and at San Francisco and Mather Field, Calif., up to 3,000 meters.

THE WEATHER ELEMENTS.

By P. C. DAY, Climatologist and Chief of Division.

PRESSURE AND WINDS.

Changes in atmospheric pressure during the month were frequent but usually not marked, and severe storms or cold waves were mainly of limited extent or duration.

Low areas of the month attended by substantial precipitation and more or less stormy conditions, were confined to a few dates, among which the following stand out most prominently: On the 1st to 3d a storm of wide extent moved from the middle Missouri Valley to the Canadian Maritime Provinces, giving snows over northern districts from the Plateau region to the Great Lakes, and moderate to heavy rains in other portions of the country from the Rocky Mountains eastward. High winds prevailed over the northern plains, reaching blizzard proportions in parts of the Dakotas; on the 14th a storm center developed over the west Gulf and moved rapidly to the northeastward over the Gulf and Atlantic Coast States during the 15th and 16th, giving heavy rains over the central and southern portions of the area, and moderate rains or snows to the northward. On the 21st a low-pressure area moved from the Southwest to the middle plains, and during the following 48 hours extended into the Great Lakes region as a storm of considerable severity. Heavy snows occurred over the regions to northward of the center, heavy rain, snow, and sleet near the center, and rains to the southward. Over the Great Lakes and the northern plains high winds occurred, and in portions of eastern Minnesota, and generally over central Wisconsin and Michigan one of the worst ice storms ever known prevailed. Enormous damage to forests, orchards, and overhead wire systems resulted from the heavy ice coating, and traffic was greatly hindered. A more complete account of this appears on pages 77–82 of this issue.

Stormy conditions prevailed near the close of the month and precipitation was widespread, and in some instances, heavy, over practically all portions of the southern half of the country.

The average pressure for the month was highest over the upper Missouri Valley and the adjacent Canadian Provinces, where it exceeded 30.20 inches, and lowest over the southern portions of the Rocky Mountain and Plateau regions. Compared with the normal it was above in all portions of the United States and the adjacent portions of Canada, save from the central Plateau and Pacific coast regions northward, where it was less than normal.

The principal high winds of the month occurred in connection with the storm of the 21st–23d, particularly during the 23d, over the lower Lakes where maximum velocities of 50 to 80 miles or more per hour were recorded.

The prevailing winds were mainly from the northwest in the Missouri and upper Mississippi Valleys; from southerly points in the Ohio Valley, lower Lakes, and generally over the southeastern States, and variable in other districts.

TEMPERATURE.

The month as a whole was marked by continuous but not severe cold over the upper Missouri Valley, and it was colder than normal over all districts from the Rocky Mountains westward. In portions of Montana and Wyoming the monthly averages were among the lowest of record, the average daily means ranging from 10° to 15° below normal. However, the extreme cold of some other years was not reached.

From the southern plains eastward and northeastward, the average temperatures were above the monthly normals, and in portions of the southeastern States the month was distinctly warm.

The principal cold periods were from the 2d to 5th over the central and southern portions of the Rocky Mountain and Plateau regions; on the 7th and 8th over the Gulf and South Atlantic States; near the middle of the month from the lower Missouri and upper Mississippi Valleys eastward to the Atlantic coast; and near or at the end in the upper Missouri Valley and northern portions of the Plateau.

The lowest temperature observed, −45°, occurred in northern Minnesota, and temperatures of −40°, or slightly lower, were observed in Montana, Wyoming, northern Wisconsin, and northern New England. Minimum temperatures below zero were reported from all the western Mountain States and over all districts eastward save in the Gulf and South Atlantic States, Arkansas, Tennessee, and Kentucky.

In the districts from the Rocky Mountains eastward the principal warm periods were from the 9th to 13th over the Great Plains and most of the Gulf States, and from the 20th to 23d over the middle Mississippi Valley and thence eastward to the Middle Atlantic and New England States.

PRECIPITATION.

The rainfall of the month was generous and usually above normal over the Gulf and South Atlantic States, the total amounts ranging from 4 to 8 inches over a wide area from eastern Texas to southern Virginia. Precipitation was generally above normal in California, the middle Plateau, northern Plains, and Great Lakes region. In portions of the upper Lake region the month was the wettest February in many years, and similar conditions prevailed in portions of California and Nevada.

Precipitation was scanty and usually less than normal in the southern Plateau and Rocky Mountain regions, over the middle and southern Great Plains, from Missouri and Illinois eastward and northeastward to the Atlantic coast, and in the far Northwest.

Over most of these districts the precipitation was sufficient for current needs, except in portions of the Southwest where drought conditions that had prevailed for long periods still continued at the end of the month.

SNOWFALL.

Although individual snowstorms were not widespread in many instances, more or less snow fell during the month over nearly all portions of the country, only the extreme southern portions receiving none.

From the northern Rocky Mountains to the Great Lakes the snowfall on the whole was heavier than usual; in some sections, notably in the vicinity of Lake Superior, the fall was the heaviest ever known in February. There was likewise unusually heavy snow in the mountains of California and Nevada, and generally over the northern and central portions of the western Mountain regions there was more snow than is usual for February.

In the central valleys there was usually but little snow, and the amounts over the eastern districts were near the normal.

There was some interruption to traffic on account of drifting over the north Central States from the snow of the 21st to the 23d, and over Oklahoma and portions of adjacent States, from the storm of the 27th to 28th.

The accumulated snow in the western mountains is generally above normal over the central and northern sections, and the prospects are good for a sufficient supply of water during the coming summer. This is especially the case in California and portions of Nevada and Utah, where the outlook is the best for a number of years. In the southern Mountain sections the amount of stored snow is less than normal, and the outlook for water during the dry season is less encouraging.

RELATIVE HUMIDITY.

In the main the departures of the average relative humidity from the normal outlined the areas of excessive and deficient precipitation, and values above the normal appear in the Gulf and Atlantic Coast States, in the upper Lake region, and thence westward to the Rocky Mountains and over the middle Plateau and the interior and southern portions of California.

In the middle and southern Plains region the negative departures were large, and likewise in the middle Mississippi Valley and parts of the lower Lakes. On the other hand, the positive departures were unusually large in portions of the Carolinas and Georgia and locally in the Lake Superior region, North Dakota, Nevada, and central California.

Severe local storms.

[The table herewith contains such data as have been received concerning severe local storms that occurred during the month. A more complete statement will appear in the annual report of the chief of bureau.]

Place.	Date.	Time.	Width of path.	Loss of life.	Value of property destroyed.	Character of storm.	Remarks.	Authority.
			Yards.					
Enterprise, Ala	5	A. m.	150-200	1	$25,000-50,000	Tornado	12 persons injured, many dwellings destroyed, and about 40 families homeless. Telephone lines and light poles razed.	Official U. S. Weather Bureau. Advertiser (Montgomery, Ala.).
Garfield, Utah (west of)	9	A. m.				Wind	Damage to box cars and buildings	Official U. S. Weather Bureau. Telegram (Salt Lake City, Utah).
Wytheville, Va., and vicinity.	14-15					Ice and snow	Severe damage to trees, telephone, and telegraph lines.	Official U. S. Weather Bureau.
Lake region	21-23					Ice, snow, and rain	Heavy losses in several States. Traffic, telephone, and light service demoralized. Homes flooded and buildings damaged. High wind at Rochester.	Official U. S. Weather Bureau. Free Press (Detroit, Mich.), Tribune (Chicago, Ill.).

STORMS AND WEATHER WARNINGS.

WASHINGTON FORECAST DISTRICT.

Storm warnings.—A storm of decided intensity was central over eastern Minnesota and moving eastward at 8 p. m. of the 1st, with rapidly falling pressure to the eastward, and southwest storm warnings were ordered displayed at 10 p. m. from Delaware Breakwater to Eastport, Me. These warnings were fully verified, the highest velocity reported being 52 miles an hour from the southwest at Atlantic City, N. J.

At 8 p. m. of the 6th a disturbance of considerable intensity was centered over Georgia and it was followed by a decided rise in pressure over the west Gulf States. Northwest storm warnings were displayed at 10 p. m. from Jacksonville, Fla., to Fort Monroe, Va. The following morning they were extended northward to Boston, Mass., and at 9.30 p. m. to Eastport, Me. They were fully verified, several stations reporting maximum velocities in excess of 50 miles an hour.

Northeast storm warnings were ordered displayed at 2 p. m. of the 12th in connection with the very rapid movement of a disturbance from the middle Mississippi Valley to the lower Lake region. However, no verifying velocities were reported.

A disturbance that developed over the western Gulf of Mexico during the 14th was central near the Louisiana coast at 8 p. m. of that date with a strong area of high pressure to the northeastward. As it was expected that this disturbance would move rapidly northeastward with increasing intensity, northeast storm warnings were ordered displayed at 9.30 p. m. on the east Gulf coast from Bay St. Louis, Miss., to Cedar Keys, Fla., and on the Atlantic coast from Cape Hatteras to Sandy Hook, N. J. The following morning they were extended to include the entire Atlantic and east Gulf coasts. These warnings were fully verified.

On the 23d southwest storm warnings were ordered displayed on the Atlantic coast from Washington, N. C., to Eastport, Me., in connection with a disturbance of marked intensity that moved rapidly across the southern Lake region and down the St. Lawrence Valley. The warnings were fully verified.

At 10 a. m. of the 28th northeast storm warnings were displayed on the east Gulf coast from Bay St. Louis, Miss., to Cedar Keys, Fla., and at 10 p. m. on the Atlantic coast from Charleston, S. C., to Delaware Breakwater. At this time a disturbance was forming over the western Gulf of Mexico while a strong area of high pressure covered practically the entire United States. On March 1 the warnings were extended northward to Nantucket, Mass. These warnings were only partially verified on account of the disturbance failing to develop the intensity expected.

Advisory warnings of strong winds were sent to the open ports on Lake Michigan on the 1st, 2d, 10th, 11th, 12th, 17th, 19th, 21st, 22d, 23d, and 27th.

Cold-wave warnings.—There were no widespread cold waves in the Washington Forecast District during the month. However, cold-wave warnings were issued for limited areas on 11 days, the most important being as follows:

February 12.—For Indiana, western Kentucky, western Tennessee, and extreme northern Mississippi.

February 15.—For Kentucky, Tennessee, Alabama, Georgia, northern and central Florida, and the South Carolina coast.

February 16.—For New England, eastern New York, and northeastern Pennsylvania.

February 22-23.—The southern Lake region, the Ohio Valley, Tennessee, the east Gulf States, northern New England, and northern and central New York.

The warnings of the 15th and 16th were fully verified and the others only partially so.

Frost warnings.—Frost warnings were issued for Mississippi on the 6th and for the east Gulf and south Atlantic States as far south as the interior of southern Florida on the 7th, 8th, and 16th.—*Charles L. Mitchell.*

CHICAGO FORECAST DISTRICT.

The month was marked by frequent movement of low-pressure areas across the forecast district, but until near the close of the third week these disturbances were attended by light precipitation because they took a northerly route. On this account, also, the mean temperature was above normal for the month, except in the northwestern States where severe cold prevailed for a long period.

The first storm, which was attended by general precipitation and which took a middle route across the Chicago district, first appeared in the Pacific Coast Region on the 18th and 19th, reaching the Great Lakes region by the morning of the 23d, accompanied by rain, snow, and sleet, and shifting gales, and followed by a sharp fall in temperature. This storm only partially broke the prolonged drouth in the winter wheat section of the Southwest, as the resulting precipitation in portions of that area was inappreciable. The snowfall accompanying this storm was especially heavy in the upper Mississippi Valley and the northern Lake region, and at several points the snow was preceded by sleet, which, together with the high winds and following snowfall, raised havoc with railroad and other means of transportation, as well as telephone and telegraph lines. The storm was especially severe in Wisconsin and eastern Minnesota, and in the Northwestern States it had all the characteristics of a "blizzard"—gales, biting cold, and snow. Forecasts of snow, or rain turning to snow, with shifting gales were made for the entire area affected well in advance of the storm, but the ensuing damage was, nevertheless, most serious, and could not be avoided.

Cold-wave warnings were issued at various times during the month, but general warnings were confined to the period from the 10th to the 12th and again from the 21st to the 23d, and these were verified at nearly every station.

Advices were sent a number of times to the live-stock interests to protect the range cattle when high winds, low temperature, and precipitation were anticipated, and, as a consequence, it is believed that there was very little loss. Under date of February 23, the observer at Rapid City, S. Dak., writes as follows:

> As I am sure western South Dakota will neglect to voice any appreciation of the weather forecaster who has saved herds of cattle the past three days, I take great pleasure in informing you that the forecasts were exceedingly accurate and the means of an enormous saving of live stock. Wide distribution was given the forecasts, and if there was any loss it was surely not the fault of the Weather Bureau service.
>
> We had a "pippin" of a blizzard here on Wednesday night and Thursday. Wires are nearly all down to-day, and trains are annulled on account of cuts being filled with drifted snow.

Forecasts for a week in advance for Montana and North Dakota were sent each Monday to the Wenatchee

Valley Traffic Association, Wenatchee, Wash., with the view of protecting their fruit in shipment to the east; and forecasts for three or four days in advance were sent to various transportation interests throughout the West and Northwest. In response to the request of the *Reporter-Enterprise*, a weekly newspaper in Oconto, Wis., forecasts were sent to it each Thursday morning which included the period ending with the following Sunday.

There is constantly an increasing pressure for forecasts for several days in advance, and it is believed that those of that character that were issued during the month were were fairly accurate and most acceptable to the recipients.—*H. J. Cox.*

NEW ORLEANS FORECAST DISTRICT.

Storm warnings were issued for the Texas coast on the 6th, 12th, 14th, 21st, 23d, and 28th, and on the Louisiana coast on the 6th, 15th, and 28th. The warnings were generally justified.

Cold-wave warnings were issued for northern and central Oklahoma and Bentonville, Ark., on the 1st, and they were partially justified. Cold-wave warnings were issued for Oklahoma and Bentonville, afternoon of the 11th, and extended on the 12th over Arkansas, northern Louisiana, the interior of east Texas, and the northern portion of west Texas. The high-pressure area moved eastward instead of southward and the warnings were verified only in the northern portion of the district. Cold-wave warnings were issued afternoon of the 21st for Oklahoma and Bentonville, Ark., were repeated and extended to the northern portion of the district on the morning of the 22d, and on the morning of the 23d the warnings were extended over Louisiana and repeated for the northeast and southwest portions of east Texas. An unusually intense cold wave made its appearance over the northern portion of the district on the 27th, and moved slowly southward, carrying freezing weather to the Gulf coast. Timely warnings were issued for this cold wave; the temperature fall in Louisiana and Arkansas was so gradual that the required fall in 24 hours was not reached.

Live-stock warnings were issued when conditions required such action.

Fire-weather warnings were issued for forest reservations in Arkansas and Oklahoma, February 21.—*I. M. Cline.*

DENVER FORECAST DISTRICT.

An unusually large number of low-pressure areas prevailed in the Denver Forecast District during February, 1922, and two South Pacific disturbances crossed the district in the third decade.

Cold-wave and live-stock warnings were issued for the eastern portions of Colorado and New Mexico on the morning of the 10th, an anticyclonic area, attended by temperatures below zero, having appeared over Alberta. The crest of the anticyclone moved eastward, however, and an area of low barometer from the North Pacific spread rapidly over the mountains, being central in southeastern Colorado by 8 p. m. of the 11th. The warnings were verified only in extreme eastern Colorado. On the morning of the 12th cold-wave warnings were issued for extreme northeastern Colorado and southeastern New Mexico. A further fall in temperature was reported in the former region and a cold wave occurred at Roswell. A disturbance appeared on the northern California coast on the morning of the 19th, moved slowly across the district, and by the 21st was over southwestern Utah. Twenty-four hours later it had reached southeastern Colorado, while the crest of a marked high-pressure area was over Saskatchewan. Cold-wave and live-stock warnings were issued for eastern Colorado. The fall in temperature in eastern Colorado was more than 30° in localities, with zero temperatures in the greater part of the area.

The cold-wave warnings were extended to that portion of New Mexico east of the mountains on the morning of the 22d. On the morning of the 23d the front of the anticyclone had spread southward to eastern Colorado, and the warnings were repeated for southeastern Colorado and southeastern New Mexico. The temperatures in eastern Colorado were close to zero, at Roswell 12° above zero, and freezing temperature occurred at El Paso. Another anticyclonic area that appeared on the northeastern slope on the 26th spread southward rapidly, and cold-wave warnings were issued on the evening of the 27th for southeastern Colorado. A disturbance from the South Pacific, central in southwestern Utah, having increased in intensity, with a barometer reading of 29.52 inches, and readings of 30.9 inches being reported in eastern Montana, a cold-wave warning for northeastern New Mexico and live-stock and heavy snowfall warnings for Colorado, northern New Mexico, northern Arizona, and Utah were issued on the morning of the 27th. Snow fell in the areas indicated, except in extreme northern Utah, with moderate to heavy amounts in Colorado and parts of northern New Mexico, and was followed by a marked cold wave in nearly all of the area for which the warnings were issued. Zero temperatures were reported in eastern Colorado and temperatures close to zero in eastern New Mexico. A still further decline in temperature occurred on the morning of March 1, the temperatures in eastern Colorado ranging from 6° to 14° below zero at regular Weather Bureau stations and from 2° above to 2° below zero in eastern New Mexico and 6° to 10° above zero in Utah and northern Arizona.—*Frederick W. Brist.*

SAN FRANCISCO FORECAST DISTRICT.

The outstanding feature of the weather in this district during February, was the succession of depressions moving in from the Pacific at a low latitude.

The first and second decades gave almost continuous rain or snow in the northern portion of the district, while the southern portion was subjected to two well-marked rainy periods; the first from the 8th to the 11th in Nevada and California, and the second from the 16th to the 27th in Nevada and northern California and from the 20th to the 27th in southern California.

The temperature was somewhat below normal for the month in all sections, but there were no abnormally cold periods in any portion of the district.

Frost warnings were issued in northern California 10 times and in southern California 7 times. While no material damage resulted frosts occurred on every occasion, and the warnings were justified.

Storm warnings were ordered on 14 days as follows: On the Washington and Oregon coast 7 times, northern California cost 9 times, and southern California coast 5 times. The warnings were generally verified, and are all believed to have been justified, as vessel reports at the time showed gales at sea.

Radio reports from vessels at sea were very beneficial to the forecaster throughout the month. They kept him in fairly close touch with conditions off the coast and indicated the fact that the storms in most instances did not progress directly inland, but upon reaching the coast small portions would become detached from the main

storm and pass inland as minor depressions, while the storm remained in the Pacific, reappearing again at short intervals. Also the end of the storms could be seen or would be indicated in a manner impossible to anticipate from the reports from coast stations.—*G. H. Willson.*

RIVERS AND FLOODS.

By H. C. FRANKENFIELD, Meteorologist.

There were two floods in the rivers of North Carolina during the month of February. The first was caused by rain combined with melting snow and high temperatures; involved the Roanoke, Tar, Neuse and Cape Fear Rivers, and began in the Roanoke River on February 4, extending over the Cape Fear River by February 8, and continuing in the lower Cape Fear until February 19. Stages were not unusually high. The second flood occurred from February 18 to 24, inclusive, and was due to heavy rains from February 13 to 16, inclusive, when the middle and lower reaches were still rather high from the previous flood. Except in the Roanoke River, the crest stages were slightly higher in the second flood than in the first.

Warnings for both floods were issued promptly and the reported losses amounted to only $10,000, while the value of property saved through the warnings was reported at $25,000.

The Peedee system of South Carolina was in flood coincidently with the second flood in the rivers of North Carolina, but the floods in the Santee system closely followed the heavy rains of the middle of the month.

These floods were more severe and the crest stages were from 4 to 9 feet above the flood stages. The Santee River had been in flood for some time past and the additional rains merely accentuated the conditions.

Considerable damage was done to bridges, fences, etc., mainly in the low country between Camden and Columbia. Live-stock losses were comparatively light.

Warnings were issued as occasion arose, and the reported value of property saved through them was $42,250. Losses amounted to $1,640, plus an unknown amount for prospective crops over 65 acres of overflowed lands.

The rains of the middle of the month were very general over the South, and the flood conditions were equally general. The flood stage of 32 feet was reached in the Savannah River at Augusta, Ga., during the night of February 16, but without resulting damage except a little that may have been caused by the inundation of some farm lands below Augusta.

Moderate floods also occurred in the other Georgia rivers for which warnings were issued at the proper time. In many places from 4 to 10 days advance notice was given, and much valuable property saved thereby, especially by lumber and cattle interests. Damage so far as reported was light.

In the Coosa, Cahaba, and Alabama Rivers of Alabama the floods were very moderate and presented nothing of special interest. The reported damage amounted to less than $1,000, and at least $5,000 worth of live stock was saved through the flood warnings.

In the Black Warrior and Tombigbee Rivers of Alabama the crest stages averaged from 1 to 3½ feet above flood stage. These floods were also well covered by warnings, and it was reported that thousands of cattle had been saved thereby. The floods were likewise of much benefit to lumbermen who depend upon them to move their timber. There was an earlier flood in the lower Tombigbee, but it passed off without incident.

Flood stages during February, 1922.

River and station.	Flood stage.	Above flood stages—dates. From—	To—	Crest. Stage.	Date.
ATLANTIC DRAINAGE.					
Roanoke:	Feet.			Feet.	
Weldon, N. C	30	4	9	35.8	5,6
	30	17	18	34.0	18
Tar:					
Rocky Mount, N. C	9	18	18	9.0	18
Tarboro, N. C	18	9	11	18.7	10
	18	17	22	20.0	20, 21
Greenville, N. C	14	9	13	15.0	11
	14	17	24	16.0	19–21
Neuse:					
Neuse, N. C	14	3	10	18.6	6
	14	16	20	18.4	17
Smithfield, N. C	14	4	11	17.6	8–10
	14	15	21	19.3	18
Cape Fear:					
Fayetteville, N. C	35	16	19	47.0	17
Elizabethtown, N. C	22	4	11	26.0	8,9
	22	16	22	32.2	19
Haw:					
Moncure, N. C	22	16	16	24.0	16
Peedee:					
Cheraw, S. C	27	15	18	35.0	17
Lynches:					
Effingham, S. C	14	21	23	15.7	21
Santee:					
Rimini, S. C	12	4	(1)	21.4	20
Ferguson, S. C	12	5	(1)	15.8	21
Catawba:					
Catawba, S. C	12	15	16	16.2	15
Wateree:					
Camden, S. C	24	16	18	30.2	16
Congaree:					
Columbia, S. C	15	16	18	22.2	17
Broad:					
Blairs, S. C	15	15	17	20.3	16
Carlton, Ga	11	15	16	16.0	15
Saluda:					
Pelzer, S. C	7	15	16	8.4	16
Chappells, S. C	14	8	8	14.7	8
	14	15	18	20.0	17
Savannah:					
Augusta, Ga	32	16	16	32.0	16
Oconee:					
Milledgeville, Ga	22	6	6	23.0	6
	22	17	18	23.3	18
Ocmulgee:					
Macon, Ga	18	17	17	18.5	17
Abbeville, Ga	11	11	16	12.7	13
	11	22	25	12.5	23,24
EAST GULF DRAINAGE.					
Apalachicola:					
Blountstown Fla	15	6	26	19.7	19
River Junction, Fla	12	7	12	16.4	9
	12	16	25	18.6	19
Chattahoochee:					
Columbus, Ga	20	16	16	29.0	16
Alabama:					
Selma, Ala	35	19	20	36.4	19
Coosa:					
Lock No. 4, Lincoln, Ala	17	18	18	17.0	18
Etowah:					
Canton, Ga	11	15	15	11.4	15
Tombigbee:					
Demopolis, Ala	39	(2)	1	40.3	1
	39	6	10	41.8	8
	39	19	23	42.3	21
Black Warrior:					
Tuscaloosa, Ala	46	16	17	49.4	17
Pearl:					
Columbia, Miss	18	8	9	18.8	8
West Pearl:					
Pearl River, La	13	4	17	14.6	7,8
GREAT LAKES DRAINAGE.					
Tittabawassee:					
Midland, Mich	18	24	24	18.9	24
Pine:					
Alma, Mich	6	23	27	8.2	25
MISSISSIPPI DRAINAGE.					
Kentucky:					
Beattyville, Ky	30	20	21	35.0	21
Green:					
Lock No. 6, Brownsville, Ky	30	22	24	33.0	24
Lock No. 4, Woodbury, Ky	33	21	26	39.0	24
Lock No. 2, Rumsey, Ky	34	25	(1)	35.6	28
Tennessee:					
Knoxville, Tenn	12	16	17	14.7	16
Riverton, Ala	32	20	21	32.4	21
Big Pigeon:					
Newport, Tenn	6	16	16	6.6	16
PACIFIC DRAINAGE.					
Mokelumne:					
Bensons Ferry, Calif	12	21	21	12.0	21

[1] Continued into March, 1922. [2] Continued from January, 1922.

Moderate local freshets early in the month over the Pascagoula system of Mississippi and Louisiana were well forecast and there was neither loss nor damage reported. Warnings were also issued for the flood stages that were reached during the third week of the month in the Tennessee River at Knoxville, Tenn., and Riverton, Ala., and in the upper Kentucky River. There was no damage reported.

The flood in the Barren and Green Rivers of Kentucky was somewhat more pronounced, and at the close of the month it was still in progress over the lower reaches. Warnings were issued well in advance of the flood and no damage was reported.

There were no other floods of consequence, although on account of heavy rains at headwaters and large accumulation of snow at lower levels, conditions became somewhat threatening early in the month in the Calaveras, Cosumnes, and Mokelumne Rivers of California. Due warning was given and no damage resulted.

MEAN LAKE LEVELS DURING FEBRUARY, 1922.

By UNITED STATES LAKE SURVEY.

[Detroit, Mich., Mar. 6, 1922.]

The following data are reported in the "Notice to Mariners" of the above date:

Data.	Lakes.[1]			
	Superior.	Michigan and Huron.	Erie.	Ontario.
Mean level during February, 1922:	*Feet.*	*Feet.*	*Feet.*	*Feet.*
Above mean sea level at New York	601.43	579.23	571.17	244.70
Above or below—				
Mean stage of January, 1922	−.19	−.09	−.34	−.03
Mean stage of February, 1921	−.33	−.61	−.68	−.76
Average stage for February, last 10 years	−.48	−.76	−.47	−.83
Highest recorded February stage	−1.05	−3.49	−2.58	−2.97
Lowest recorded February stage	+.67	+.07	+.54	+.87
Average relation of the February level to:				
January level	....	.00	−.10	.00
March level	....	−.10	−.10	−.20

[1] Lake St. Clair's level: In February, 573.25 feet.

EFFECT OF WEATHER ON CORPS AND FARMING OPERATIONS, FEBRUARY, 1922.

By J. WARREN SMITH, Meteorologist.

The greater part of February, 1922, was extremely cold and unfavorable for stock and outdoor operations in the Northwestern States, especially in North Dakota and Montana. It was warm for the season in the Central and the Southern States where considerable farm work was accomplished, although there was some delay by frequent rains and wet soil in the Central and the East Gulf States. Field work was delayed in California by rains the latter part of the month, but some sugar-beet planting was done there and bean planting was begun. Some corn was planted in the Gulf States and cotton planting was begun in extreme southern Texas at about the average date.

The severe drought that had prevailed throughout the fall and winter months in the Southwest continued until the latter part of February, when it was brought to an end by general precipitation in most districts. Good snows occurred in Kansas and general rains were received in Oklahoma. Wheat and ranges were greatly benefited and material improvement was reported by the end of the month. The weather continued favorable for wheat and other fall-sown grains in the Central and the Eastern States and they continued generally in satisfactory condition in these sections.

Spring-oats seeding made satisfactory progress in the South the latter part of the month, but this work was stopped in the central Plains area by heavy precipitation during the last few days.

The month was favorable for the growth of most truck crops in the Gulf and South Atlantic States, except that some damage was done by frost in northern Florida and it was somewhat too warm there for celery and lettuce during the first part. Winter truck was badly injured by frost in California during the first week of the month.

The cold weather and snow-covered ranges were unfavorable for stock in the Northwestern States, the severe storm and extremely cold weather the latter part of the month being especially harmful. There was much loss of stock in North Dakota, and it suffered greatly in South Dakota, Montana, and Wyoming. The precipitation the latter part of the month caused marked improvement in ranges in most lower Great Plains grazing areas while pastures improved in the Central and the Southern States.

The mild weather developed fruit trees rather rapidly in the Southern States and by the close of the month early deciduous fruits were blooming in the Gulf Coast districts with a few blossoms coming out as far north as South Carolina. Fruit trees were badly damaged in the western Lake region by a severe ice storm the latter part of the month, especially in north-central Michigan where orchards were almost denuded of branches over considerable areas. Citrus fruit trees made good growth in Florida and produced a heavy bloom, while the harvest of navel oranges was general in southern California.

CLIMATOLOGICAL TABLES.[1]

CONDENSED CLIMATOLOGICAL SUMMARY.

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, February, 1922.

Section.	Temperature.								Precipitation.					
	Section average.	Departure from the normal.	Monthly extremes.						Section average.	Departure from the normal.	Greatest monthly.		Least monthly.	
			Station.	Highest.	Date.	Station.	Lowest.	Date.			Station.	Amount.	Station.	Amount.
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	51.3	+6.7	2 stations	83	[2] 12	Valley Head	15	7	6.12	+0.77	Milstead	9.39	Scottsboro	3.87
Alaska														
Arizona	44.4	−1.6	Goodyear	88	20	Bly R. S.	−28	4	0.68	−0.61	Ashdale R. S.	2.80	3 stations	0.00
Arkansas	47.8	+5.6	2 stations	84	11	Gravette	10	7	4.89	+1.61	Portland	9.70	Osceola	1.70
California	45.5	−3.0	Blythe	91	11	Fort Bidwell	−19	14	6.98	+2.57	Deer Creek	31.84	Sterling	0.00
Colorado	26.0	−0.5	2 stations	78	[2] 17	Crested Butte	−33	[2] 7	1.05	−0.06	Cumbres	4.38	2 stations	0.10
Florida	65.3	+5.3	Lake Wales	90	27	2 stations	24	8	2.84	−0.51	Cottage Hill	8.78	Temple Terraces	0.27
Georgia	55.5	+7.6	2 stations	86	[2] 13	3 stations	14	[2] 8	6.35	+1.38	Tallapoosa	9.13	Quitman	3.84
Hawaii	67.7	−0.5	6 stations	84	[2] 23	2 stations	42	14	7.92	+1.53	Honomu, Hawaii	39.09	2 stations	0.00
Idaho	22.6	−4.5	Murphy	56	17	Stanley	−34	28	1.75	−0.14	Alpha	4.27	Challis	0.39
Illinois	32.8	+5.1	2 stations	75	22	5 stations	−4	[2] 13	1.41	−0.67	Carbondale	3.04	Aurora	0.44
Indiana	33.8	+4.6	3 stations	76	[2] 21	Plymouth	0	16	1.63	−1.02	Rome	3.11	South Bend	0.53
Iowa	23.7	+3.2	2 stations	70	21	Inwood	−20	13	1.59	+0.44	Fayette	4.56	Spencer	0.40
Kansas	33.8	+2.9	Medicine Lodge	82	10	3 stations	−3	28	1.13	−0.14	Marion	3.40	2 stations	0.07
Kentucky	41.3	+5.7	2 stations	76	[2] 21	3 stations	4	[2] 16	3.58	−0.02	Williamsburg	6.59	Ashland	1.82
Louisiana	58.9	+6.3	Baton Rouge	88	19	Calhoun	19	8	5.29	+0.82	Dodson	12.89	Delta Farms	1.98
Maryland-Delaware	37.3	+4.5	Hancock, Md.	79	23	Oakland, Md.	−11	17	3.18	−0.09	Crisfield, Md	6.35	Boyds, Md.	2.04
Michigan	21.8	+3.5	2 stations	65	22	Humboldt	−35	16	2.73	+0.96	Sidnaw	6.12	Coldwater	0.65
Minnesota	7.2	−2.8	Grand Rapids	46	8	2 stations	−45	14	2.14	+1.43	Willmar	4.89	Hallock	0.38
Mississippi	53.7	+5.3	2 stations	86	12	2 stations	19	8	6.43	+1.56	Grenada	10.18	Hernando	3.23
Missouri	35.4	+4.1	Caruthersville (2)	80	[2] 10	Bethany (3)	−5	13	1.79	−0.44	Poplar Bluff	4.28	St. Charles	0.84
Montana	11.3	−10.0	Big Timber	62	7	Busby	−42	28	0.76	−0.03	Heron	3.57	Valier	0.01
Nebraska	23.3	−1.5	2 stations	74	[2] 17	Neleigh	−16	13	0.38	−0.35	Blair	1.65	3 stations	0.00
Nevada	31.2	−3.8	Logandale	80	12	Vya	−30	28	1.63	+0.65	Lamoille	4.29	Mina	0.29
New England	23.4	+1.6	Bridgeport, Conn.	60	20	3 stations	−40	[2] 17	2.83	−0.38	Portland, Me.	5.05	Williamstown, Mass.	1.52
New Jersey	33.6	+4.0	Camp Dix	73	23	Culvers Lake	−18	17	2.94	−0.63	Cape May City	4.60	Sussex	1.80
New Mexico	37.2	−0.2	2 stations	82	[2] 10	Dulce	−28	5	0.44	−0.25	Chama	3.29	12 stations	0.00
New York	26.3	+4.7	Dansville	73	23	Wanakena	−39	15	2.56	−0.27	Dannemora	5.30	Angelica	0.41
North Carolina	47.6	+5.7	Pinehurst	83	20	Cullowhee	3	8	5.78	+1.89	Edenton	9.85	Banners Elk	2.97
North Dakota	0.8	−7.1	Skaar	45	18	Skaar	−39	27	1.21	+0.72	Fullerton	3.16	Langdon	0.10
Ohio	33.9	+5.9	2 stations	76	[2] 21	Summerfield	−3	17	1.68	−0.92	Prospect	4.00	North Bass Island	0.67
Oklahoma	44.2	+4.8	Pauls Valley	87	10	Beaver	−1	28	1.31	−0.11	Broken Bow	4.04	Erick	0.30
Oregon	33.6	−3.3	2 stations	67	28	Fremont	−25	28	3.36	−0.38	Brookings	10.89	Warmsprings	0.31
Pennsylvania	33.0	+5.5	3 stations	74	23	Ebensburg	−19	17	1.99	−0.90	Somerset	3.61	Neshaminy Falls	0.67
Porto Rico														
South Carolina	52.6	+5.5	Garnett	84	23	Walhalla	14	8	6.62	+2.19	Calhoun Falls	10.54	Darlington	3.23
South Dakota	9.7	−6.7	Spearfish	62	9	Pollock	−37	14	0.98	+0.69	Redfield	3.65	Tyndall	0.10
Tennessee	45.8	+5.6	3 stations	80	21	2 stations	5	8	4.34	+0.21	Ashwood	6.20	Mountain City	2.49
Texas	54.6	+4.3	Mission	100	12	Romero	−2	28	1.77	−0.03	Marshall	6.35	Clint	0.00
Utah	26.9	−2.6	St. George	70	19	Hanksville	−22	2	1.62	+0.21	Silver Lake	6.68	Lemay	T.
Virginia	40.9	+4.6	Franklin	78	23	Dale Enterprise	−13	17	4.05	+0.89	Runnymede	6.70	Winchester	1.86
Washington	29.6	−4.8	Mottinger	65	18	Wilbur	−20	1	2.17	−1.26	Wind River	9.32	Mottinger	0.13
West Virginia	38.2	+6.4	Moorefield	77	23	Brandywine	−14	17	2.89	−0.21	Davis	5.57	Morgantown	0.94
Wisconsin	15.8	+0.5	Solon Springs	52	9	Danbury	−42	16	3.11	+1.95	Pine River	5.27	Danbury	1.04
Wyoming	15.8	−5.6	Torrington	69	9	Lovell	−42	2	0.85	+0.04	Dutch Joe	3.28	2 stations	T.

[1] For description of tables and charts, see REVIEW, January, 1921, page 41.

[2] Other dates also.

TABLE I.—*Climatological data for Weather Bureau stations, February, 1922.*

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.									Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity.	Precipitation.			Wind.					Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow, sleet, and ice on ground at end of month.
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max. + mean min. ÷ 2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.				Total.	Departure from normal.	Days with 0.01 inch or more.	Total movement.	Prevailing direction.	Maximum velocity. Miles per hour.	Maximum velocity. Direction.	Maximum velocity. Date.						
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F		°F	°F.		°F	°F.	°F.	°F.	%	In.	In.		Miles.								0-10	In.	In.
New England.							27.2	+1.7										75	3.08	−0.2										6.5		
Eastport	76	67	85	29.96	30.05	+0.07	22.6	+1.2	50	20	30	−10	17	15	44	21	17	78	3.10	−0.5	15	8,770	w.	44	nw.	24	7	6	15	6.6	24.0	6.7
Greenville, Me	1,070	6	....	28.83	30.06	.....	14.8	.....	42	20	25	−25	18	4	40	.....	.....	.....	2.77	.....	10	.....	.....	.....	.....	.....	11	3	14	....	27.8	26.0
Portland, Me	103	82	117	29.97	30.10	+.08	24.2	+0.4	53	20	32	−8	17	16	35	21	16	74	5.05	+1.4	11	5,784	nw.	35	se.	2	10	6	12	5.7	27.7	20.5
Concord	288	70	79	29.78	30.11	+.07	23.6	0.0	53	21	33	−16	18	14	47	.....	.....	.....	2.65	−0.6	10	3,542	nw.	29	w.	24	9	5	14	6.2	19.7	15.7
Burlington	404	11	48	29.63	30.10	+.07	21.0	+3.1	51	23	30	−20	17	12	38	.....	.....	.....	1.98	+0.6	12	8,640	s.	54	s.	23	5	12	11	6.3	20.5	2.8
Northfield	876	12	60	29.11	30.11	+.06	18.2	+1.0	52	23	31	−21	17	6	47	15	12	82	3.14	+0.9	14	5,620	s.	36	n.	24	6	9	13	6.4	30.8	18.5
Boston	125	115	188	29.95	30.09	+.05	32.0	+4.0	56	20	40	−4	17	24	37	28	21	66	2.64	−0.8	11	6,634	w.	36	w.	28	7	5	16	6.8	15.5	T.
Nantucket	12	14	90	30.06	30.07	+.03	32.1	−0.5	47	2	38	6	18	26	29	30	28	85	4.91	+1.8	13	10,547	sw.	43	e.	27	5	5	18	7.6	18.2	T.
Block Island	26	11	46	30.06	30.09	+.03	32.2	+1.0	50	24	38	0	17	27	32	30	26	78	3.16	−1.1	12	12,842	nw.	55	nw.	8	8	5	15	6.5	10.3	0.0
Providence	160	215	251	29.91	30.09	+.04	31.4	+2.4	57	20	39	−5	17	24	36	28	22	71	2.42	−2.0	14	8,769	nw.	49	nw.	28	10	5	13	6.0	13.9	1.8
Hartford	159	122	140	29.93	30.11	+.05	30.6	+3.4	56	20	38	−6	17	23	36	26	21	70	2.02	−1.5	10	5,103	nw.	33	nw.	24	6	4	18	7.2	11.0	1.4
New Haven	106	74	153	30.00	30.13	+.06	31.3	+3.0	59	20	39	−5	17	24	33	28	23	75	2.84	−0.9	8	6,466	n.	32	nw.	13	6	10	12	6.4	8.5	T.
Middle Atlantic States.							36.5	+3.7										75	2.90	−0.4										6.5		
Albany	97	102	115	30.02	30.13	+.06	27.0	+3.4	51	23	35	−10	17	19	34	25	22	82	1.46	−1.1	12	5,571	s.	37	s.	19	10	9	9	5.1	8.8	0.5
Binghamton	871	10	84	29.14	30.10	+.02	29.0	+4.3	65	23	37	−10	17	21	31	.....	.....	.....	1.12	−0.8	12	4,644	nw.	28	s.	23	3	8	17	7.4	8.8	2.0
New York	314	414	454	29.77	30.12	+.04	34.5	+3.8	66	23	42	−2	17	27	31	30	23	68	2.97	−0.8	13	12,692	nw.	64	nw.	8	5	10	13	6.7	6.7	0.0
Harrisburg	374	94	104	29.74	30.15	+.06	34.3	+4.4	69	23	42	4	17	27	28	30	24	70	2.29	−0.4	11	4,769	nw.	38	s.	23	6	11	11	6.1	8.0	T.
Philadelphia	117	123	190	30.02	30.15	+.05	36.7	+3.9	71	23	44	4	17	29	35	33	27	72	2.62	−0.8	13	6,997	nw.	34	s.	23	8	8	12	6.1	5.2	0.0
Reading	325	81	98	29.79	30.16	.....	34.6	.....	72	23	42	2	17	27	32	31	27	77	2.69	−0.8	12	4,976	nw.	30	nw.	24	6	11	11	6.1	10.4	0.0
Scranton	805	111	119	29.24	30.13	+.05	31.5	+4.6	67	23	40	−7	17	23	28	28	23	74	1.55	−1.2	11	5,053	sw.	32	sw.	3	5	9	14	6.6	8.6	1.0
Atlantic City	52	37	48	30.08	30.14	+.03	36.6	+3.6	63	20	43	4	17	30	26	33	30	82	3.67	+0.4	15	12,544	nw.	58	sw.	2	5	14	9	6.3	12.6	0.0
Cape May	18	13	49	30.15	30.17	+.06	36.2	+2.1	58	23	42	6	17	30	25	33	30	82	4.60	+1.3	14	6,499	nw.	36	nw.	8	7	7	14	6.2	14.9	0.0
Sandy Hook	22	10	55	30.10	30.13	.....	33.6	.....	63	23	40	3	17	28	28	30	25	74	2.27	.....	14	10,643	nw.	56	nw.	8	5	12	11	6.1	3.6	0.0
Trenton	190	159	183	29.92	30.13	.....	34.2	.....	70	23	42	0	17	26	37	31	26	75	2.25	−0.9	10	7,990	n.	54	w.	3	6	8	14	6.6	6.6	0.0
Baltimore	123	100	113	30.02	30.15	+.04	38.4	+3.8	74	23	46	8	17	31	27	33	28	70	2.94	−0.6	15	4,016	n.	29	sw.	23	6	10	12	6.2	4.4	0.0
Washington	112	62	85	30.02	30.15	+.04	38.6	+4.1	72	23	46	9	17	31	31	33	27	68	2.86	−0.6	14	4,941	n.	33	n.	24	3	12	13	7.0	3.0	0.0
Lynchburg	681	153	188	29.38	30.15	+.04	42.0	+3.8	72	27	51	10	17	33	34	37	33	75	3.32	−0.2	16	4,729	w.	33	nw.	3	5	11	12	6.4	4.7	0.0
Norfolk	91	170	205	30.05	30.16	+.06	44.8	+3.0	74	23	53	13	17	37	29	40	36	77	4.85	+1.1	12	9,637	ne.	42	ne.	7	5	6	17	7.0	8.8	0.0
Richmond	144	11	52	30.00	30.16	+.05	41.9	+2.0	73	11	50	8	17	33	35	37	34	80	3.81	+0.7	18	5,896	ne.	39	sw.	23	3	13	12	7.1	5.3	0.0
Wytheville	2,304	49	56	27.70	30.14	+.02	39.6	+4.5	68	23	48	11	17	32	29	36	32	80	3.12	−1.0	15	4,614	w.	29	w.	2	4	7	17	7.5	6.0	0.0
South Atlantic States.							52.9	+5.1										82	5.56	+1.5										6.9		
Asheville	2,255	70	84	27.75	30.15	+.02	45.2	+6.7	73	12	54	13	8	37	28	39	35	76	4.06	−0.6	10	6,470	se.	34	e.	28	2	15	11	6.7	6.9	0.0
Charlotte	779	55	62	29.29	30.15	+.03	48.4	+4.3	73	23	56	20	17	40	26	44	40	78	7.12	+2.7	13	4,401	sw.	25	nw.	7	5	9	14	7.0	1.2	0.0
Hatteras	11	12	50	30.12	30.13	+.02	49.8	+3.2	71	26	56	20	17	43	21	47	45	88	5.55	+1.1	11	10,743	sw.	57	n.	7	7	5	16	7.1	T.	0.0
Manteo	12	5	42	.....	.....	.....	45.4	.....	74	11	55	16	17	36	.....	.....	.....	.....	5.19	.....	9	.....	ne.	.....	.....	.....	8	5	15	....	0.0	0.0
Raleigh	376	103	110	29.74	30.15	+.04	48.0	+4.7	76	23	57	13	17	39	29	43	41	82	7.14	+2.8	12	5,866	sw.	35	ne.	7	5	11	12	6.8	1.8	0.0
Wilmington	78	81	91	30.08	30.17	+.05	52.4	+4.7	76	21	61	20	17	44	31	48	45	84	3.15	−0.2	13	5,494	sw.	43	w.	7	4	9	15	7.0	T.	0.0
Charleston	48	11	92	30.11	30.16	+.04	56.4	+4.7	77	23	64	28	17	49	28	52	49	84	5.63	+2.2	11	7,170	sw.	36	nw.	7	5	9	14	6.9	0.0	0.0
Columbia, S. C.	351	41	57	29.78	30.17	+.06	53.4	+5.6	77	21	62	24	17	45	29	48	44	78	5.73	+1.1	13	5,470	ne.	28	sw.	12	4	8	16	7.1	T.	0.0
Due West	711	10	55	29.39	30.18	.....	50.2	.....	76	21	58	21	8	42	32	.....	.....	.....	7.11	.....	14	6,072	sw.	30	sw.	12	6	7	15	6.9	0.8	0.0
Greenville, S. C.	1,039	113	122	29.02	30.13	.....	49.0	.....	73	21	57	20	8	41	27	44	41	79	7.21	.....	13	6,620	sw.	48	w.	3	7	6	15	6.8	0.0	0.0
Augusta	180	62	77	29.94	30.14	+.02	54.9	+5.9	78	12	63	25	8	46	31	50	47	81	5.05	+0.7	11	4,127	s.	25	nw.	7	4	9	15	6.9	T.	0.0
Savannah	65	150	194	30.08	30.15	+.03	58.7	+6.2	80	13	67	28	8	50	30	54	52	87	6.64	+3.4	11	8,257	sw.	54	w.	7	8	4	16	6.8	0.0	0.0
Jacksonville	43	209	245	30.11	30.16	+.04	62.0	+5.1	81	24	70	28	8	54	32	57	55	86	5.56	+2.1	11	8,582	s.	51	w.	7	4	10	14	6.7	0.0	0.0
Florida Peninsula.							69.9	+2.6										79	1.70	−0.9										3.7		
Key West	22	10	64	30.09	30.11	+.04	72.4	+1.6	83	6	78	52	8	67	17	66	64	80	1.44	−0.2	10	8,338	se.	39	nw	16	17	10	1	2.9	0.0	0.0
Miami	25	71	79	30.13	30.16	.....	70.3	+1.5	81	6	76	40	8	65	28	64	61	76	3.14	+0.4	4	7,200	e	30	nw.	21	16	9	3	3.6	0.0	0.0
Sand Key	23	39	72	30.10	30.13	+.06	71.4	.....	79	3	74	53	8	69	16	67	64	78	2.22	.....	8	12,220	e.	48	nw.	16	17	9	2	3.3	0.0	0.0
Tampa	35	79	92	30.12	30.16	+.06	66.9	+4.6	84	25	76	35	8	58	29	60	57	82	0 52	−2.8	4	4,946	sw.	27	w.	7	5	20	3	5.0	0.0	0.0
East Gulf States.							56.2	+5.5										80	6.02	+1.3										6.8		
Atlanta	1,174	190	216	28.89	30.15	+.03	50.1	+4.9	74	21	58	20	8	42	27	46	44	84	6.55	+1.9	11	8,480	nw.	48	nw.	6	4	6	18	7.8	T.	0.0
Macon	370	78	87	29.74	30.14	+.02	55.4	+6.5	80	12	64	23	8	46	33	50	46	76	5.78	+1.2	10	4,829	s.	29	se.	6	5	9	14	6.9	T.	0.0
Thomasville	273	49	58	29.84	30.14	+.02	61.2	+6.2	81	13	70	27	8	52	34	55	51	79	4.64	+0.2	8	3,525	sw.	24	w.	6	6	6	16	6.5	0.0	0.0
Pensacola	56	149	185	30.07	30.13	+.02	59.6	+4.1	73	24	66	31	8	54	28	57	55	87	2.93	−1.6	7	9,428	se.	58	nw.	6	4	6	18	7.0	0.0	0.0
Anniston	741	9	57	29.36	30.17	+.05	51.8	+6.0	78	21	61	20	8	43	30	.....	.....	.....	6.98	+2.3	11	4,709	nw.	27	nw.	15	6	6	16	6.8	1.0	0.0
Birmingham	700	11	48	29.38	30.16	+.04	52.8	+4.5	78	12	61	22	8	44	29	46	42	73	5.02	+0.3	11	5,762	s.	27	se.	1	6	6	16	7.0	0.4	0.0
Mobile	57	125	161	30.06	30.12	+.01	59.4	+6.2	77	12	68	30	16	51	28	55	53	85	5.65	+0.3	9	7,328	s.	45	nw.	6	4	12	12	6.4	0.0	0.0
Montgomery	223	100	112	29.90	30.15	+.03	57.0	+7.0	80	12	66	27	8	48	32	51	47	76	6.69	+1.2	11	5,074	s.	34	n.	15	6	7	15	6.6	0.0	0.0
Corinth	469	6	.....	.....	.....	.....	49.0	.....	80	21	58	20	8	41	32	.....	.....	.....	5.51	.....	11	.....	s.	.....	.....	.....	4	14	10	....	T.	0.0
Meridian	375	85	93	29.72	30.13	+.02	54.4	+5.3	82	12	63	26	8	46	27	49	44	76	9.12	+4.2	12	4,657	n.	30	n.	15	5	7	16	6.9	T.	0.0
Vicksburg	247	65	73	29.84	30.14	+.04	54.2	+3.3	79	12	62	26	8	46	30	49	46	80	9.65	+5.0	12	5,893	s.	32	nw.	23	4	8	16	7.1	T.	0.0
New Orleans	53	76	84	30.06	30.12	+.03	62.7	+6.4	82	13	71	35	8	54	28	58	55	82	3.25	−1.2	12	5,123	se.	31	n.	6	4	13	11	6.3	0.0	0.0
West Gulf States.							53.8	+4.1										75	2.84	+0.1										6.3		
Shreveport	249	77	93	29.84	30.11	+.02	54.0	+4.0	80	19	62	31	7	46	26	48	44	76	5.40	+1.8	8	6,214	se.	38	w.	22	9	9	10	5.7	T.	0.0
Bentonville	1,303	11	44	.....	.....	.....	42.0	+3.5	76	10	52	15	28	32	37	.....	.....	.....	1.87	.....	7	5,380	s.	32	s.	22	8	8	12	....	3.5	3.0
Fort Smith	457	79	94	29.60	30.09	−.01	47.2	+5.4	79	10	56	24	28	38	31	42	36	69	2.44	−0.3	8	6,241	e.	44	nw.	22	5	9	14	6.9	0.6	1.7
Little Rock	357	136	144	29.72	30.10	−.01	48.2	+4.1	78	11	56	25	16	40	29	43	37	68	3.95	−0.2	9	7,159	s.	33	nw.	15	7	3	18	7.0	0.1	0.6
Brownsville	57	4	26	.....	.....	.....	66.7	.....	86	5	76	35	16	57	35	.....	.....	.....	3.17	.....	5	.....	n.	.....	.....	.....	.....	.....	.....	....	0.0	0.0
Corpus Christi	20	69	77	30.05	30.08	+.03	61.2	+3.5	80	10	68	36	28	54	38	56	53	80	0.51	−1.5	9	9,144	n.	44	s.	22	9	7	12	5.6	0.0	0.0
Dallas	512	109	117	29.53	30.08	.....	52.4	.....	88	11	62	21	28	43	31	.....	.....	.....	2.38	.....	10	6,612	s.	42	s.	22	7	10	11	6.1	0.9	T.
Fort Worth	670	106	114	29.34	30.06	−.01	52.5	+4.4	88	11	62	20	28	42	33	45	40	68	2.00	+0.7	8	7,856	s.	34	s.	22	7	11	10	6.1	T.	0.0
Galveston	54	106	114	30.04	30.10	+.03	59.9	+4.3	75	12	66	40	15	54	26	57	55	88	3.03	−0.1	7	8,247	se.	42	nw.	6	8	8	12	5.8	0.0	0.0
Groesbeck	461	11	56	29.59	30.08	.....	54.1	.....	82	10	63	25	28	45	32	.....	.....	.....	3.35	.....	9	9,403	n.	50	s.	22	4	10	14	7.0	0.0	0.0
Houston	138	111	121	29.93	30.08	.....	60.1	+6.1	84	12	68	36	16	52	26	.....	.....	.....	2.25	.....	12	6,197	s.	42	s.	22	5	12	11	6.5	0.0	0.0
Palestine	510	64	72	29.55	30.09	+.01	54.2	+3.3	81	10	62	29	28	46	32	48	43	71	4.40	+1.0	10	6,649	ne.	32	s.	22	5	12	11	6.7	0.0	0.0
Port Arthur	34	58	66	30.04	30.08	.....	59.2	.....	76	12	66	34	16	53	26	55	53	87	3.48	.....	10	7,237	se.	39	nw.	6	9	6	13	6.1	0.0	0.0
San Antonio	701	119	132	29 33	30 06	+.01	58.2	+3.8	86	10	68	27	28	48	32	50	44	66	1.26	−0.5	9	6,320	ne.	60	nw.	6	9	11	8	5.2	0.0	0.0
Taylor	582	55	63	29.48	30.09	+.03	54.6	+3.3	83	10	64	24	28	45	34	.....	.....	.....	2.56	0.0	9	7,512	s.	38	s.	22	3	13	12	6.9	0.0	0.0

TABLE I.—*Climatological data for Weather Bureau stations, February, 1922*—Continued.

Districts and stations.	Elevation of instruments: Barometer above sea level.	Elevation of instruments: Thermometer above ground.	Elevation of instruments: Anemometer above ground.	Pressure: Station, reduced to mean of 24 hours.	Pressure: Sea level, reduced to mean of 24 hours.	Pressure: Departure from normal.	Temperature of the air: Mean max. + mean min. ÷ 2.	Temperature of the air: Departure from normal.	Temperature of the air: Maximum.	Temperature of the air: Date.	Temperature of the air: Mean maximum.	Temperature of the air: Minimum.	Temperature of the air: Date.	Temperature of the air: Mean minimum.	Temperature of the air: Greatest daily range.	Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity.	Precipitation: Total.	Precipitation: Departure from normal.	Precipitation: Days with 0.01 inch or more.	Wind: Total movement.	Wind: Prevailing direction.	Wind: Maximum velocity: Miles per hour.	Wind: Maximum velocity: Direction.	Wind: Maximum velocity: Date.	Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow, sleet, and ice on ground at end of month.
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F		°F	°F.		°F	°F.	°F.	°F.	%	In.	In.		Miles.								0–10	In.	In.
Ohio Valley and Tennessee.							39.5	+3.9										73	2.68	−0.9										7.1		
Chattanooga	762	189	213	29.33	30.16	+0.03	48.5	+4.8	74	21	56	20	16	41	24	43	38	72	4.56	−0.4	12	5,771	se.	44	n.	15	3	11	14	7.2	T.	0.0
Knoxville	996	102	111	29.07	30.14	+.02	46.8	+6.0	75	21	55	19	17	39	25	42	37	74	4.09	−0.8	10	5,088	sw.	35	sw.	12	3	8	17	7.5	1.6	0.0
Memphis	399	76	97	29.72	30.16	+.04	47.2	+3.9	78	21	54	22	16	41	26	43	39	75	3.30	−1.0	10	7,097	n.	38	w.	23	5	4	19	7.4	0.6	0.0
Nashville	546	168	191	29.56	30.16	+.04	45.0	+3.9	73	21	53	19	8	37	34	40	35	71	3.89	−0.4	12	7,948	s.	48	w.	23	3	7	18	7.5	0.1	0.0
Lexington	989	193	230	29.06	30.16	+.05	38.2	+2.6	70	22	46	12	16	30	33				3.12	−0.1	14	10,745	sw.	48	sw.	2	3	7	18	7.5	2.7	0.0
Louisville	525	219	255	23.57	30.17	+.06	39.6	+3.0	71	22	47	14	16	32	35	35	30	72	2.66	−1.1	10	9,870	s.	44	w.	23	8	10	10	6.1	T.	0.0
Evansville	431	139	175	29.68	30.16	+.05	38.9	+3.1	72	22	46	15	16	31	38	35	30	71	2.38	−0.7	10	9,304	ne.	44	nw.	23	5	8	15	6.6	0.3	0.0
Indianapolis	822	194	230	29.22	30.13	+.03	33.4	+2.7	70	22	41	7	16	26	37	30	25	72	1.46	−1.6	9	9,496	s.	46	w.	23	5	8	15	7.1	0.8	T.
Royal Center	736	11	55	29.28	30.11		30.4		68	22	38	3	16	23	36				0.86		7	8,643	w.	45	w.	23	4	9	15	7.2	1.2	0.0
Terra Haute	575	96	129	29.48	30.12		34.4		70	22	42	8	16	27	40	31	26	72	1.14		8	7,902	nw.	35	sw.	22	5	10	13	6.7	0.1	0.0
Cincinnati	628	11	51	29.46	30.16	+.06	36.0	+3.6	71	22	43	12	16	29	35		29	73	1.68	−1.6	12	6,755	sw.	39	sw.	2	4	12	12	7.1	2.3	0.0
Columbus	824	179	222	29.23	30.13	+.04	33.8	+2.8	68	22	41	8	16	27	32	30	25	71	1.58	−1.5	9	9,202	nw.	50	w.	3	2	11	15	7.5	2.5	0.0
Dayton	899	181	216	29.13	30.11		34.4	+4.4	69	22	41	11	16	28	34	31	28	78	1.47	−1.6	11	8,859	sw.	44	sw.	23	4	11	13	6.7	0.5	0.0
Elkins	1,947	59	67	28.03	30.16	+.06	37.4	+5.9	73	23	48	1	17	27	36	33	30	81	4.26	+1.1	18	4,444	nw.	36	nw.	2	1	13	14	7.8	5.2	T.
Parkersburg	638	77	84	29.48	30.15	+.05	38.4	+4.5	72	22	47	8	17	30	35	34	28	69	1.57	−1.7	14	4,862	nw.	36	sw.	23	6	9	13	6.4	3.6	0.0
Pittsburgh	842	353	410	29.20	30.13	+.05	35.2	+3.4	70	23	43	5	17	27	38	32	27	71	1.57	−1.1	14	8,900	nw.	62	w.	23	1	6	21	8.0	3.4	0.0
Lower Lake Region.							28.3	+3.6										75	1.97	−0.5										7.3		
Buffalo	767	247	280	29.23	30.09	.03	27.1	+3.1	60	23	34	0	17	20	38	25	22	80	2.01	−0.8	17	13.188	sw.	84	sw.	23	2	5	21	8.2	8.9	0.5
Canton	448	10	61	29.57	30.07		20.1	+2.1	46	19	29	−22	17	11	36				2.92	+0.4	14	8,008	w.	54	sw.	19	9	7	12	6.0	20.2	5.2
Oswego	335	76	91		30.09	+.03	26.2	+2.3	58	23	34	−9	17	19	37				3.00	+0.4	16	8,866	s.	42	sw.	23	2	7	19		17.1	0.5
Rochester	523	86	102	29.51	30.10	+.04	28.1	+4.2	66	23	35	0	17	21	46	25	20	71	2.63	−0.2	17	7,051	w.	52	w.	23	2	9	17	7.8	8.1	0.0
Syracuse	597	97	113	29.44	30.11	+.04	27.3	+3.5	64	23	35	−10	17	19	38				2.83	+1.0	19	8,847	s.	52	sw.	23	2	8	18	7.5	13.0	1.6
Erie	714	130	166	29.30	30.09	+.02	29.8	+3.7	65	23	37	1	17	22	43	27	23	76	1.25	−1.6	11	10,705	nw.	62	w.	23	2	13	13	7.0	4.7	0.0
Cleveland	762	190	201	29.27	30.12	+.05	31.7	+4.9	68	22	38	7	17	25	38	28	24	74	1.31	−1.3	14	9,991	s.	52	w.	23	0	12	16	7.6	4.8	T.
Sandusky	629	62	103	29.40	30.11	+.04	31.4	+4.3	68	22	38	8	16	25	36				1.00	−1.4	12	9,983	sw.	60	w.	23	1	13	14	7.2	3.2	0.0
Toledo	628	208	243	29.41	31.12	+.05	30.6	+3.8	65	22	38	7	16	24	37	27	22	72	0.83	−1.1	8	10,970	sw.	68	sw.	23	5	8	15	6.0	2.8	T.
Fort Wayne	856	113	124	29.17	30.13		30.6	+4.8	67	22	38	10	16	24	37	28	24	78	0.87		9	7,760	sw.	43	sw.	23	2	9	17	7.3	2.5	0.0
Detroit	730	218	245	29.28	30.11	+.05	28.4	+3.4	57	22	35	5	16	22	37	26	22	76	1.91	−0.3	12	8,359	sw.	56	w.	23	4	7	17	7.4	6.6	0.0
Upper Lake Region.							20.1	+0.7										81	2.54	+0.8										6.7		
Alpena	609	13	92	29.38	30.07	+.04	19.4	+1.6	40	19	27	−10	17	11	36	18	14	82	3.09	+1.3	14	8,452	w.	42	se.	1	7	9	12	6.4	22.4	15.5
Escanaba	612	54	60	29.38	30.08	+.02	15.6	+0.3	37	1	24	−11	16	7	34	14	11	86	2.71	+1.4	12	6,892	nw.	48	ne.	23	15	1	12	4.7	24.3	17.5
Grand Haven	632	54	89	29.37	30.09	+.04	26.8	+2.6	55	23	33	7	16	20	38	24	20	78	2.91	+1.0	14	9,416	w.	50	w.	23	1	9	18	8.1	8.2	0.0
Grand Rapids	707	70	87	29.30	30.10	+.05	27.5	+2.0	55	23	34	7	16	21	40	24	20	77	2.25	+0.3	11	4,703	w.	34	w.	23	2	7	19	7.9	9.1	0.0
Houghton	684	62	99	29.30	30.05	+.01	14.0	−2.0	41	10	22	−12	14	6	35				4.84	+3.1	18	8,074	e.	50	w.	10	4	5	19	7.9	47.7	42.0
Lansing	878	11	62	29.11	30.08		26.0	+4.4	55	23	34	0	16	18	43	23	20	82	0.97	−1.0	11	5,282	sw.	30	sw.	23	2	11	15	7.6	4.6	T.
Ludington	637	60	66	29.35	30.07		24.0		43	10	30	6	16	18	30	22	18	81	5.11		12	8,417	w.	42	sw.	1	4	8	16	7.0	12.8	1.3
Marquette	734	77	111	29.25	30.09	+.04	17.0	+1.1	38	10	24	−6	16	10	26	14	10	78	3.00	+1.3	16	7,645	w.	40	sw.	11	7	7	14	6.6	31.6	27.0
Port Huron	638	70	120	29.36	30.08	+.03	26.3	+4.3	54	23	33	1	16	19	40	21	21	82	1.07	−1.1	12	8,716	nw.	58	w.	23	1	14	13	6.8	3.7	T.
Saginaw	641	69	77	29.37	30.10		24.4		45	23	32	−2	16	17	35	22	19	80	1.85	−0.2	12	4,853	nw.	23	w.	23	2	9	17	7.4	4.1	T.
Sault Ste. Marie	614	11	52	29.35	30.08	+.05	12.6	−0.8	38	1	23	−20	24	2	41	12	10	90	1.94	+0.5	20	5,689	nw.	42	nw.	19	4	9	15	7.0	19.1	25.6
Chicago	823	140	310	29.19	30.11	+.03	29.4	+1.9	68	22	37	2	16	21	38	26	20	66	0.74	−1.4	9	9,552	w.	47	sw.	23	7	6	15	6.2	0.9	T.
Green Bay	617	100	144	29.38	30.08	+.02	15.6	−1.6	42	1	25	−12	16	6	34	14	11	82	4.54	+2.9	11	8,261	sw.	54	sw.	1	10	6	12	5.9	15.8	11.0
Milwaukee	681	125	139	29.32	30.09	+.03	23.4	+1.5	47	9	32	−2	16	15	29	21	15	70	1.45	−0.4	9	7,715	nw.	39	sw.	1	10	7	11	5.4	3.5	0.0
Duluth	1,133	11	47	28.80	30.10	+.02	7.6	−6.0	36	10	16	−22	16	−1	41	6	5	93	4.24	+3.2	13	10,988	w.	50	ne.	22	11	5	12	5.5	34.4	28.0
North Dakota.							0.9	−6.0										87	0.85	+0.3										5.7		
Moorhead	940	50	58	29.10	30.18	+.07	2.6	−4.4	27	17	13	−30	14	−8	40	1	−2	83	0.72	0.0	10	7,054	n.	36	nw.	10	6	10	12	6.2	12.3	11.5
Bismarck	1,674	8	57	28.34	30.25	+.13	2.2	−6.1	35	7	13	−26	24	−8	36	1	2	87	1.55	+1.0	5	6,634	nw.	40	nw.	10	10	9	9	4.9	17.8	18.0
Devils Lake	1,482	11	44	28.48	30.17	+.06	−.4	−4.9	29	7	10	−26	14	−11	35	−2	−3	90	0.64	+0.1	7	8,753	nw.	44	nw.	10	9	4	15	6.1	9.3	7.6
Ellendale	1,457	10	56	28.51	30.16		2.2		36	17	13	−26	14	−8	36				1.48		8	11,488	nw.	57	n.	23	7	9	12	5.9	17.0	14.7
Grand Forks	835	12	89																													
Williston	1,878	41	48	28.09	30.21	+.10	−.8	−8.7	34	7	10	−26	13	−11	37	−1	−3	89	0.50	0.0	6	5,382	w.	30	nw.	10	11	5	12	5.5	8.3	6.3
Upper Mississippi Valley.							26.8	+2.2										73	2.22	+0.5										5.2		
Minneapolis	918	102	208	29.08	30.12		11.6		41	10	21	−15	13	2	38				3.25	+2.5	11	8,375	w.	38	nw.	19	8	11	9	5.6	13.6	12.4
St. Paul	837	236	261	29.15	30.11	+.02	11.0	−4.0	39	10	21	−14	13	1	38				3.69	+2.8	12	9,082	w.	44	nw.	19	11	10	7	4.8	20.9	13.2
La Crosse	714	11	48	29.27	30.09	+.01	17.6	−0.8	48	10	28	−9	13	7	38				4.04	+3.0	9	3,945	s.	30	sw.	1	11	5	12	5.5	7.5	2.0
Madison	974	70	78	29.02	30.12	+.05	20.3	+0.7	47	10	30	−5	13	11	32	18	15	82	3.90	+2.4	9	7,205	nw.	45	sw.	1	10	9	9	5.2	3.2	1.0
Wausau	1,247	4		28.68	30.09		12.0		38	10	22	−25	16	2	32				2.79		10		nw.				13	5	10	5.0	23.5	26.5
Charles City	1,015	10	49		30.13	+.03	18.0	+2.9	46	17	27	−10	13	9	31				2.93	+2.0	8	5,632	nw.	34	w.	1	6	12	10		3.8	0.5
Davenport	606	71	79	29.45	30.14	+.08	28.0	+4.2	66	22	38	−1	13	18	33	24	18	71	1.34	−0.2	5	6,138	nw.	33	w.	23	10	9	9	5.2	2.2	1.4
Des Moines	861	84	97	29.17	30.12	+.01	26.4	+2.3	61	22	37	−4	13	16	36	22	16	68	0.64	−0.4	6	6,060	nw.	41	sw.	1	13	8	7	4.5	0.4	T.
Dubuque	698	81	96	29.34	30.13	+.04	23.8	+2.2	52	10	33	−3	13	14	35	21	16	76	1.44	+0.1	9	5,345	nw.	31	sw.	1	11	11	6	5.0	2.1	0.6
Keokuk	614	64	78	29.44	30.15	+.04	30.6	+4.0	68	22	40	2	13	21	35	26	20	66	1.56	−0.1	6	6,441	nw.	40	sw.	1	11	11	6	4.6	2.1	1.0
Cairo	356	87	93	29.74	30.13	+.01	40.9	+3.3	72	22	48	14	7	33	38	37	32	72	2.81	−0.5	9	8,394	n.	38	sw.	22	3	7	18	7.4	T.	0.1
Peoria	609	11	45	29.45	30.14	+.04	29.9	+4.0	71	22	39	3	16	21	32	26	23	80	1.98	−0.7	7	6,169	w.	34	w.	1	11	11	6	4.5	0.6	T.
Springfield, Ill	644	10	91	29.42	30.12	+.02	32.4	+3.3	71	22	41	8	16	24	34	28	23	73	0.86	−1.9	8	7,003	nw.	32	s.	22	10	12	6	4.8	0.4	0.0
Hannibal	534	74	109	29.54	30.14	+.03	33.0	+3.9	74	22	43	4	13	23	36				1.18	−0.4	6	7,583	nw.	38	s.	22	9	13	6	4.6	T.	0.0
St. Louis	567	265	303	29.51	30.13	+.02	36.4	+2.9	74	22	45	12	7	28	31	31	25	65	1.52	−1.2	9	10,054	s.	50	s.	22	6	11	11	5.9	0.8	0.7
Missouri Valley.							24.3	−0.1										74	1.12	+0.1										4.5		
Columbia, Mo.	781	11	84	29.26	30.13	+.02	34.4	+4.3	74	22	44	7	13	25	35				1.23	−0.9	6	7,219	n.	33	sw.	17	11	11	6	5.1	3.1	3.0
Kansas City	963	161	181	29.06	30.13	+.02	33.3	+3.4	73	21	43	1	13	23	39	28	20	58	1.49	−0.1	4	9,347	n.	37	sw.	1	16	5	7	3.8	4.8	4.2
St. Joseph	967	11	49	29.04	30.12		31.2		74	21	42	0	13	20	39	26	19	64	1.58		5	7,484	nw.	48	w.	22	16	8	4	3.6	T.	T.
Springfield, Mo.	1,324	98	104	28.68	30.12	+.01	38.2	+4.6	73	10	48	12	13	29	30	33	28	73	2.02	−0.2	7	8,291	se.	39	s.	22	9	11	8	5.1	5.1	5.0
Iola	984	11	50	29.04	30.12	+.02	36.4	+4.4	78	10	47	7	13	25	40				4.04	+1.2	6	6,091	ne.	30	ne.	27	7	13	8	5.4	5.0	5.0
Topeka	987	92	107				32.8	+2.8	74	21	44	2	13	22	47				2.48	+1.1	5	8,371	n.	37	s.	8	14	6	8	4.3	1.9	1.4
Drexel	1,299	10	53	28.69	30.14		22.4		57	22	34	−9	13	11	39	19	17	85	1.10		3	8,164	nw.	46	nw.	1	11	10	8	4.7	T.	0.0
Lincoln	1,189	11	84	28.82	30.14	+.04	26.0	+1.0	64	22	37	−3	13	15	47	22	17	74	0.66	0.0	3	7,674	n.	50	nw.	1	13	8	7	4.4	T.	0.0
Omaha	1,105	115	122	28.92	30.16	+.05	24.8	+1.1	59	22	36	−5	13	14	38	21	15	68	0.91	+0.2	3	6,975	nw.	33	n.	10	15	8	5	3.7	0.1	0.0
Valentine	2,598	47	54	27.31	30.18	+.09	16.2	−5.0	50	9	28	−12	28	4	39	13	10	84	0.32	−0.3	5	5,954	w.	37	nw.	1	9	11	8	4.9	4.8	T.
Sioux City	1,135	94	164	28.89	30.17	+.05	18.2	−1.6	48	19	28	−8	13	8	35	15	11	74	0.58	0.0	7	9,480	nw.	55	w.	1	10	12	6	4.7	3.3	0.2
Huron	1,306	59	74	28.73	30.22	+.10	6.8	−6.1	38	17	18	−23	13	−4	38	5	2	83	1.20	+0.8	6	7,054	w.	38	w.	1	22	2	4	3.0	10.7	8.0
Pierre	1,572	7	75	28.45	30.22	+.11	9.6	−7.3	44	10	20	−18	28	0	44	7	4	81	0.49	0.0	6	6,511	nw.	44	nw.	1	10	7	11	5.1	10.2	3.2
Yankton	1,233	49	57	28.77	30.17	+.05	15.2	−3.0	45	18	26	−13	13	4	45				0.74	+0.2	4	6,318	w.	36	w.	1	9	11	8	5.2	3.4	2.0

TABLE I.—*Climatological data for Weather Bureau stations, February, 1922*—Continued.

Districts and stations.	Elevation of instruments: Barometer above sea level.	Elevation of instruments: Thermometer above ground.	Elevation of instruments: Anemometer above ground.	Pressure: Station, reduced to mean of 24 hours.	Pressure: Sea level, reduced to mean of 24 hours.	Pressure: Departure from normal.	Temperature of the air: Mean max. + mean min. ÷ 2.	Temperature of the air: Departure from normal.	Temperature of the air: Maximum.	Temperature of the air: Date.	Temperature of the air: Mean maximum.	Temperature of the air: Minimum.	Temperature of the air: Date.	Temperature of the air: Mean minimum.	Temperature of the air: Greatest daily range.	Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity.	Precipitation: Total.	Precipitation: Departure from normal.	Precipitation: Days with 0.01 or more.	Wind: Total movement.	Wind: Prevailing direction.	Wind: Maximum velocity: Miles per hour.	Wind: Maximum velocity: Direction.	Wind: Maximum velocity: Date.	Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow, sleet, and ice on ground at end of month.
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F		°F	°F.		°F	°F.	°F.	°F.	%	In.	In.		Miles.								0.10	In.	In.
Northern Slope.							14.0	−7.5										73	0.74	−0.1										5.3		
Billings	3,140	5					13.9		53	9	28	−23	23	0	46				0.36		4		ne.				15	7	6		5.0	3.0
Havre	2,505	11	44	27.42	30.25	+0.18	.4	−14.6	38	16	12	−31	27	−11	42	0	−2	86	0.70	+0.2	10	4,531	nw.	30	sw.	7	9	9	10	4.9	7.0	9.6
Helena	4,110	87	112	25.75	30.15	+.04	13.6	−8.6	50	16	23	−22	23	4	46	11	6	71	0.90	+0.2	9	4,328	sw.	31	sw.	18	7	6	15	6.5	16.7	4.8
Kalispell	2,973	48	56		30.09	+.01	15.4	−8.4	41	16	25	−13	1	6	38				0.60	−0.9	7	3,248	nw.	25	sw.	18	8	8	12		6.4	7.0
Miles City	2,371	26	48	27.54	30.27	+.18	4.5	−12.3	42	17	16	−34	28	−7	36	2	−1	86	0.84	+0.3	10	3,233	se.	34	ne.	9	11	14	3	4.2	9.6	9.6
Rapid City	3,259	50	58	26.59	30.22	+.14	14.8	−8.7	55	9	26	−12	24	3	54	10	4	64	0.44	0.0	6	5,210	n.	48	sw.	9	7	11	10	6.0	4.8	3.4
Cheyenne	6,088	84	101	23.88	30.05	+.02	22.9	−2.4	56	21	34	−12	23	13	36	19	10	58	0.85	+0.3	6	11,402	w.	61	w.	1	6	16	6	5.3	9.0	3.5
Lander	5,372	60	68	24.54	30.13	+.05	16.2	−5.6	46	9	28	−17	23	4	39	13	8	70	0.40	−0.2	5	3,219	sw.	38	w.	12	13	10	5	4.5	4.0	2.4
Sheridan	3,790	10	47	26.07	30.18		11.4		54	9	25	−19	28	−2	43	8	4	74	0.21		7	3,151	nw.	40	sw.	9	8	10	10	5.4	2.9	5.0
Yellowstone Park	6,200	11	48	23.74	30.10	.00	12.9	−6.7	39	9	24	−25	28	2	38	12	8	77	1.84	0.0	14	5,628	s.	42	s.	9	4	12	12	6.5	23.5	29.0
North Platte	2,821	11	51	27.11	30.16	+.09	24.3	−0.3	61	17	38	−4	23	11	39	19	13	69	0.05	−0.4	3	4,903	w.	29	nw.	23	14	8	6	4.2	0.3	T.
Middle Slope.							34.7	+2.3										58	0.94	+0.2										4.9		
Denver	5,292	106	113	24.63	30.02	+.01	31.4	+0.3	63	9	43	−1	28	20	38	24	13	53	0.40	−0.1	6	5,464	s.	38	w.	1	9	13	6	4.6	7.0	3.2
Pueblo	4,685	80	86	25.22	30.00	.00	33.2	+1.4	69	21	48	−2	28	18	45	25	13	50	0.37	−0.1	3	5,539	nw.	48	nw.	8	5	19	4	5.1	3.7	3.0
Concordia	1,392	50	58	28.61	30.14	+.05	31.0	+2.2	70	21	43	2	28	19	53	25	19	67	1.12	+0.4	3	6,608	n.	37	nw.	22	13	9	6	4.4	2.2	2.2
Dodge City	2,509	11	51	27.44	30.12	+.06	34.0	+2.9	76	8	48	−1	28	20	45	26	18	64	1.73	+1.0	3	7,224	se.	35	s.	21	15	9	4	3.7	8.5	8.5
Wichita	1,358	139	158	28.61	30.09	+.01	35.8	+2.8	76	10	47	5	28	25	44	30	20	58	1.38	+0.3	5	9,575	ne.	57	s.	8	9	11	8	5.4	5.0	5.0
Altus	1,410	5					44.8		82	10	58	11	28	31	44				0.58		2		n.				4	3	11		2.7	2.0
Broken Arrow	765	11	52	29.24	30.08		42.4		78	20	53	12	28	32	34				1.18		5	10,369	n.	44	s.	8	7	9	12	6.0	4.0	4.0
Muskogee	652	4					45.9		83	10	56	17	28	36	32				1.75		5		nw.				9	10	9		3.5	1.0
Oklahoma City	1,214	10	47	28.78	30.09	+.02	42.8	+4.3	80	20	54	12	28	31	43	34	25	57	0.64	−0.3	4	7,955	n.	36	s.	21	6	16	6	5.4	3.0	3.0
Southern Slope.							48.0	+3.5										46	0.54	−0.3										5.4		
Abilene	1,738	10	52	28.24	30.07	+.02	50.4	+5.6	91	11	62	10	28	39	34	39	26	47	0.46	−0.6	6	8,473	s.	40	s.	22	6	10	12	6.6	1.1	1.1
Amarillo	3,676	10	49	26.25	30.05	+.03	40.8	+3.6	79	20	55	3	28	27	41	32	23	58	1.44	+0.6	4	9,125	sw.	36	n.	6	8	16	4	5.1	7.7	6.6
Del Rio	944	64	71	29.07	30.07	+.07	57.6	+4.0	89	12	70	26	28	46	37				0.11	−0.8	1	6,498	se.	44	n.	22	9	8	11	5.7	0.0	0.0
Roswell	3,566	75	85	26.36	30.02	+.04	43.2	+0.7	80	11	60	5	28	27	49	32	13	34	0.16	−0.4	2	6,119	s.	42	nw.	5	13	10	5	4.0	1.4	0.7
Southern Plateau.							46.1	−1.6										51	0.43	−0.2										4.2		
El Paso	3,762	110	133	26.19	29.98	+.03	50.5	+1.1	79	20	64	21	28	37	40	37	18	30	T.	−0.5	0	7,717	w.	48	w.	5	11	15	2	4.1	T.	0.0
Santa Fe	7,013	57	66	23.17	30.01	+.03	32.2	+0.2	58	21	43	−1	28	21	44	26	16	54	0.51	−0.3	2	5,984	n.	45	s.	21	9	8	11	5.7	8.6	5.0
Flagstaff	6,908	10	59																													
Phoenix	1,108	76	81	28.85	30.02	+.03	54.4	0.0	80	20	68	28	3	41	36	44	34	54	0.42	−0.3	3	3,237	e.	26	nw.	27	13	9	6	4.0	0.0	0.0
Yuma	141	9	54	29.88	30.03	+.03	55.9	−3.3	81	18	69	31	4	43	34	45	32	45	0.16	−0.4	3	4,029	n.	25	w.	27	17	8	3	3.3	0.0	0.0
Independence	3,957	9	41	25.94	30.04	−.02	37.4	−6.3	70	18	47	2	1	28	33	33	27	70	1.07	+0.3	5	5,097	se.	44	sw.	11	13	8	7	4.1	5.0	0.0
Middle Plateau.							29.2	−3.8										73	1.76	+0.7										6.3		
Reno	4,532	74	81	25.40	30.04	−.04	30.0	−5.6	52	7	39	−4	13	21	30	27	23	73	4.06	+2.3	14	4,515	w.	38	sw.	26	4	10	14	6.8	32.5	T.
Tonopah	6,090	12	20	23.98	30.04		29.5		50	17	36	8	3	23	23	27	22	74	0.54	−0.2	5	7,579	se.	37	se.	8	10	14	4	4.7	6.8	0.0
Winnemucca	4,344	18	56	25.56	30.06	−.03	25.9	−7.4	48	8	36	−7	13	15	35	24	21	78	2.10	+1.2	12	5,289	ne.	40	sw.	10	6	9	13	6.7	21.7	4.5
Modena	5,479	10	43	24.54	30.00	−.04	29.0	−2.6	53	20	40	−14	2	18	40	24	17	64	0.89	−0.3	7	7,882	sw.	55	sw.	11	10	9	9	5.1	3.6	0.1
Salt Lake City	4,360	163	203	25.59	30.06	−.02	29.8	−3.1	57	20	37	10	28	23	26	27	23	75	2.36	+1.0	11	5,024	nw.	42	sw.	9	6	4	18	7.1	27.3	2.0
Grand Junction	4,602	60	68	25.35	30.00	−.04	31.4	−0.1	62	20	42	−7	6	21	35	27	22	72	0.62	0.0	11	3,251	nw.	32	sw.	11	2	9	17	7.3	4.3	0.0
Northern Plateau.							28.8	−3.3										73	1.15	−0.2										7.0		
Baker	3,471	48	53	26.39	30.06	−.06	24.6	−3.3	41	17	32	−3	1	17	31	23	19	76	0.87	−0.5	16	4,167	se.	25	se.	8	4	9	15	6.3	11.3	0.8
Boise	2,739	78	86	27.16	30.08	−.04	31.9	−1.9	51	8	38	8	2	25	20	29	23	67	1.00	−0.4	13	3,927	se.	31	se.	8	5	5	18	7.4	8.1	0.0
Lewiston	757	40	48	29.25	30.08	−.03	32.6	−3.6	51	18	39	6	1	26	23				1.10	−0.2	10	2,644	e.	32	w.	8	3	9	16	7.2	8.9	0.0
Pocatello	4,477	60	68	25.42	30.09	−.01	23.8	−4.3	45	9	31	0	15	16	31	22	18	78	1.94	+1.1	15	6,916	se.	48	s.	9	3	8	17	7.2	23.4	0.0
Spokane	1,929	101	110	27.95	30.07	−.02	26.2	−3.9	49	8	35	−9	1	18	33	24	18	70	1.04	−0.9	11	3,897	ne.	25	sw.	8	8	5	15	6.3	10.4	3.5
Walla Walla	991	57	65	28.96	30.06	−.05	33.4	−3.0	56	8	40	9	1	27	26	31	26	72	0.97	−0.6	10	3,972	s.	32	se.	6	2	9	17	7.6	2.4	T.
North Pacific Coast Region.							39.7	−1.6										77	3.28	−2.0										7.2		
North Head	211	11	56	29.74	29.98	−.08	40.0	−2.1	57	28	44	26	24	36	19	38	34	81	3.54	−2.2	18	11,113	e.	64	s.	16	6	9	13	6.1	0.1	0.0
Port Angeles	29	8	53	29.95	29.98		36.6		50	6	42	21	1	31	20				2.11	−0.9	14	3,860	s.	34	sw.	3	7	4	17	6.8	1.2	0.0
Seattle	125	215	250	29.88	30.02	−.04	39.4	−1.1	54	28	45	22	1	34	24	35	30	73	1.74	−2.0	14	6,621	se.	40	w.	16	5	4	19	7.3	0.5	0.0
Tacoma	213	113	120	29.78	30.01	−.05	38.4	−2.0	53	28	44	18	1	32	27				2.00	−3.1	13	4,563	sw.	29	ne.	19	3	9	16	7.2	T.	0.0
Tatoosh Island	86	7	57	29.85	29.95	−.05	39.3	−1.7	51	26	43	31	1	36	12	37	34	82	6.56	−2.2	17	14,302	e.	60	s.	6	5	2	21	7.4	0.8	0.0
Yakima	1,071	4					30.0		52	18	40	−1	1	20	33				0.18		2		ne.				10	10	8		2.4	0.0
Medford	1,425	4																														
Portland, Oreg.	153	68	106	29.86	30.02	−.06	39.9	−1.4	56	6	46	22	1	34	20	36	31	72	3.29	−2.4	14	4,916	e.	25	e.	24	2	2	24	8.3	T.	0.0
Roseburg	510	9	57	29.47	30.02	−.08	41.2	−1.4	62	6	49	26	1	34	31	38	34	79	3.70	−0.9	15	1,819	s.	20	sw.	26	3	12	13	7.0	0.7	0.0
Middle Pacific Coast Region.							47.4	−2.1										78	5.27	+1.2										6.3		
Eureka	62	73	89	29.98	30.05	−.06	45.0	−1.8	62	15	51	30	2	39	21	42	40	82	9.75	+2.7	17	4,638	se.	37	sw.	10	7	7	14	6.7	0.0	0.0
Point Reyes	490	7	18	29.49	30.01		47.8	−1.4	58	14	51	38	11	44	14				2.69		16	14,653	nw.	80	s.	10	8	5	15	6.0	0.0	0.0
Red Bluff	332	50	56	29.67	30.03	−.08	45.5	−3.8	63	5	53	28	2	38	32	42	37	73	4.25	+0.6	15	5,105	se.	33	se.	10	10	3	15	6.1	0.0	0.0
Sacramento	69	106	117	29.99	30.06	−.03	47.1	−3.1	60	8	53	31	2	41	24	45	42	82	4.18	+1.0	14	6,334	se.	42	se.	10	10	4	14	5.7	0.0	0.0
San Francisco	155	208	243	29.88	30.05	−.05	50.2	−1.1	63	28	56	38	1	45	18	46	42	76	5.15	+1.4	16	5,848	sw.	45	sw.	10	9	4	15	6.4	0.0	0.0
San Jose	141	12	110	29.92	30.07		49.0	−1.6	67	6	58	28	2	40	34				3.01	+0.5	12	4,714	se.	36	sw.	8	6	6	16	6.7	0.0	0.0
South Pacific Coast Region.							52.2	−0.7										74	3.50	+1.1										5.5		
Fresno	327	89	98	29.73	30.09	+.01	49.6	+0.4	71	16	58	29	2	41	28	44	39	71	2.19	+0.9	11	4,157	nw.	29	se.	10	5	10	13	6.2	0.0	0.0
Los Angeles	338	159	191	29.71	30.08	+.02	54.0	−1.1	75	15	61	38	3	47	27	49	44	76	3.47	+0.6	8	4,261	e.	27	s.	9	11	7	10	5.4	0.0	0.0
San Diego	87	62	70	29.98	30.08	+.02	53.7	−0.9	72	15	61	37	4	47	27	50	46	78	1.86	−0.1	10	3,941	nw.	38	s.	20	11	9	8	5.0	0.0	0.0
San Luis Obispo	201	32	40	29.87	30.09	−.02	51.4	−1.1	73	6	60	32	1	43	35	46	41	71	6.49	+2.9	13	3,517	n.	38	s.	9	8	9	11	5.4	0.0	0.0
West Indies.																																
San Juan, P. R.	82	8	54	29.97	30.06		74.5		86	7	79	67	4	70	15				5.42	+2.9	22	12,072	e.	42	e.	15	3	19	6	5.6	0.0	0.0
Panama Canal.																																
Balboa Heights	118	7	97																													
Colon	25	5	71																													
Alaska.																																
Juneau	80	11	49	29.97	30.06		23.8		44	24	29	0	8	18	25	20	12	65	3.83		10	5,102	ne.	41	ne.	16	13	3	12	5.0	10.4	0.0

TABLE II.—*Data furnished by the Canadian Meteorological Service, February, 1922.*

Stations.	Altitude above mean sea level, Jan. 1, 1919.	Pressure.			Temperature of the air.						Precipitation.		
		Station reduced to mean of 24 hours.	Sea level reduced to mean of 24 hours.	Departure from normal.	Mean max.+mean min.÷2.	Departure from normal.	Mean maximum.	Mean minimum.	Highest.	Lowest.	Total.	Departure from normal.	Total snowfall.
	Feet.	*In.*	*In.*	*In.*	°*F*	°*F*	°*F*	°*F*	°*F*	°*F*	*In.*	*In.*	*In.*
St. John's, N. F.	125												
Sydney, C. B. I.	48	29.98	30.03	+0.11	16.0	−3.3	26.7	5.4	40	−19	3.79	−0.30	30.5
Halifax, N. S.	88	29.92	30.03	+.08	22.1	−0.3	31.5	12.8	42	−21	3.96	−1.20	24.3
Yarmouth, N. S.	65												
Charlottetown, P. E. I.	38	29.97	30.01	+.06	14.8	−2.8	23.9	5.8	40	−23	2.07	−0.99	20.7
Chatham, N. B.	28												
Father Point, Que.	20	30.02	30.05	+.07	9.9	−1.6	19.8	0.1	38	−22	1.17	−1.04	8.7
Quebec, Que.	296	29.73	30.07	+.08	13.3	+1.5	22.0	4.6	41	−22	2.97	−0.30	29.3
Montreal, Que.	187	29.85	30.07	+.05	16.4	+1.9	24.3	8.6	42	−15	2.75	−0.32	19.4
Stonecliffe, Ont.	489												
Ottawa, Ont.	236	29.82	30.11	+.09	15.3	+3.6	24.8	5.8	43	−21	2.66	−0.03	23.0
Kingston, Ont.	285	29.78	30.12	+.08	22.3	+4.5	30.6	14.1	45	−14	2.41	−0.13	9.5
Toronto, Ont.	379	29.66	30.09	+.05	26.5	+5.0	33.9	19.1	48	−7	2.95	+0.34	12.5
Cochrane, Ont.	930												
White River, Ont.	1,244	28.64	30.04	+.02	1.2	+1.0	17.9	−13.1	33	−46	0.95	−0.57	9.5
Port Stanley, Ont.	592	29.45	30.11	+.05	26.1	+3.3	33.1	19.2	42	−1	1.55	−1.66	9.3
Southampton, Ont.	656	29.34			22.3	+2.4	29.9	14.7	42	−8	3.37	+0.47	23.3
Parry Sound, Ont.	688	29.32	30.05	+.04	16.0	+1.7	26.0	6.0	39	−30	4.10	+1.18	30.2
Port Arthur, Ont.	644	29.34	30.08	+.03	9.5	+3.1	18.9	0.2	34	−23	1.27	+0.37	12.7
Winnipeg, Man.	760	29.28	30.18	+.08	0.4	+2.0	10.1	−9.3	24	−25	0.74	−0.24	7.4
Minnedosa, Man.	1,690	28.25	30.20	+.11	−2.4	+0.3	7.1	−11.9	18	−30	0.91	−0.30	9.1
Le Pas, Man.	860												
Qu'Appelle, Sask.	2,115	27.77	30.19	+.11	−3.6	−3.0	7.3	−14.6	28	−38	1.14	+0.41	11.4
Medicine Hat, Alb.	2,144												
Moose Jaw, Sask.	1,759												
Swift Current, Sask.	2,392	27.50	30.31	+.14	−0.9	−8.9	9.1	−10.9	32	−31	0.32	−0.42	3.2
Calgary, Alb.	3,428												
Banff, Alb.	4,521												
Edmonton, Alb.	2,150												
Prince Albert, Sask.	1,450	28.52	30.21	+.12	−4.0	−1.0	6.0	−14.0	20	−34	0.53	−0.16	5.3
Battleford, Sask.	1,592	28.34	30.21	+.12	−2.9	−3.0	7.8	−13.7	25	−35	0.30	−0.07	3.0
Kamloops, B. C.	1,262												
Victoria, B. C.	230	29.73	29.99	−.01	37.9	−1.6	43.4	32.5	52	25	1.99	−2.11	7.3
Barkerville, B. C.	4,180	25.51	29.98	+.07	9.0	−9.9	19.3	−1.2	35	−23	4.85	+1.79	48.5
Triangle Island, B. C.	680												
Prince Rupert, B. C.	170	29.77			29.9		36.6	23.2	47	8	2.36		6.5
Hamilton, Ber.	151	30.09	30.26	+.15	63.8	+2.3	60.8	57.8	75	47	3.33	−1.11	0.0

SEISMOLOGICAL REPORTS FOR FEBRUARY, 1922.

W. J. HUMPHREYS, Professor in Charge.

[Weather Bureau, Washington, Apr. 3, 1922.]

TABLE 1.—*Noninstrumental earthquake reports, February, 1922.*

Day.	Approximate time, Greenwich civil.	Station.	Approximate latitude.	Approximate longitude.	Intensity Rossi-Forel.	Number of shocks.	Duration.	Sounds.	Remarks.	Observer.
1921.	*H. m.*	CALIFORNIA.	° ′	° ′			*Sec.*			
Feb. 1	13 18	Nevada City	39 15	121 00	3	1		None	Felt by several	B. H. Preston.
4	20 20	Spreckels	36 38	121 36	2	1	15-20	Faint	Felt by many	Spreckels Sugar Co.
	20 25	Salinas	36 41	121 39	3	1	4 *ca.*	None	do	Dr. E. D. Eddy.
5	1 28	Eureka	40 48	124 10	3	1	2	do	do	J. M. Jones.
	19 15	Julian	33 05	116 37	5	1	6	Rumbling	do	J. H. L. Vogt.
6	2 35	Escondido	33 06	117 05	4	1		None	do	H. L. Harlow.
9	7 07	Julian	33 05	116 37	4	1	10	Rumbling	Felt by several	J. H. L. Vogt.
21	19 10	Calexico	32 41	115 30	2	1	2	Faint	do	W. S. Pratt.
	19 13	do	32 41	115 30	2	1	2	do		Do.
26	2 00	Brawley	32 59	115 40	4	1		Yes	Felt by many	M. D. Witter.
28	19 51	Los Gatos	37 12	121 58	3-4	2	1	None	Felt by all	I. H. Snyder.
		IDAHO.								
19	21 *ca.*	Wayan	43 00	111 20	4?	2	10-15	Rattling	Felt by many	L. C. Mathews.
		LATE REPORTS.								
		OREGON.								
Jan. 31	13 20	Ashland	42 20	122 45	3	1	6	None	Felt by many	J. Dodge.
		Bend	44 00	121 20	2	1		do	Felt by several?	Bend Bulletin.
	13 30	Brookings	42 00	124 15	5?	2	60, 6		Felt by many	J. Reyan.
		do	42 00	124 15	2	1		None	do	P. S. Allyn.
	13 10	Central Point	42 20	123 00	5	3	3, 3, 3	do	Felt by nearly everyone	K. Beebe.
		Chiloquin	42 40	122 00					Slight shocks felt by few	
	13 20	Cottage Grove	43 40	123 00	2	3		None	Felt by several	C. E. Stewart.
		Eugene	44 00	123 00			Brief.	Faint	Felt by many	L. Gaetschins.
	13 25	Florence	44 00	124 00	2	1	30	None	do	R. E. Abben.
		Medford	42 20	122 50	4?		180 *ca*		do	R. V. Earl.
	13 20	Oakridge	43 40	122 30	5	2	5		Felt by everyone	F. M. French.
		Port Orfard	42 40	124 30		1		None	Felt by a few	J. D. Louets.
	13 15?	Prospect	42 40	122 30	2	2	30	do	Felt by several	E. B. Price.
	13 20	Talent	42 10	122 50	3	1	5-10	do	Felt by a few	F. C. Reimer.
	13 30	Williams	42 10	123 10	2-3	2	Few.	do	Felt by many	J. W. Tuney.
	13 15	Winchester Bay	43 15	123 25						Oscar Wiren.
	13 20	Wolf Creek	42 40	123 10	3	2		None	Felt by several	Mrs. F. M. Stason.

TABLE 2.—*Instrumental seismological reports, February, 1922.*

Time used: Mean Greenwich, midnight to midnight. Nomenclature: International.

[For significance of symbols and description of stations, see REVIEW for January, 1922.]

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
ARIZONA. *U. S. C. & G. S. Magnetic Observatory, Tucson.*								
1922.			*H. m. s.*	*Sec.*	*μ*	*μ*	*Km.*	
Feb. 16		P_E	3 22 07					N not operating during February.
		L_E	3 32 41	16				
		M_E	3 34 19	13	30			
		F_E	4 03 ..					
28		P_E	21 26 13					
		S_E	21 29 39					
		L_E	21 31 23	13				
		M_E	21 35 03	12	10			
		F_E	21 50 ..					
CALIFORNIA. *Theosophical University, Point Loma.*								
1922.			*H. m. s.*	*Sec.*	*μ*	*μ*	*Km.*	
Feb. 3					150	300		Tremors during preceding 24 hours.
DISTRICT OF COLUMBIA. *U. S. Weather Bureau, Washington.*								
1922.			*H. m. s.*	*Sec.*	*μ*	*μ*	*Km.*	
Feb. 14		P?	12 39 18					
		S?	12 45 45					
		F	12 50 ..					
14		eL	13 55 ..					Very small amplitudes.
		L	14	24				
		F	14 10 ..					
16		P	3 21 52				2400	
		S	3 25 52					
		L	3 27 30					
		L	3 30 30	18				
		F	4 10 *ca.*					
19		eL	22 06 18	20				
		F	22 20 *ca.*					
28		e	21 23 ..					
		L	21 32 ..					
		F	21 45 ..					
HAWAII. *U. S. C. & G. S. Magnetic Observatory, Honolulu.*								
1922.			*H. m. s.*	*Sec.*	*μ*	*μ*	*Km.*	
Feb. 2		e_N	3 28 40			[1]2,000		Nothing definite.
		F_N	3 39 ..					
21		L	18 25 18	3				Local shock; recorded on D variometer from 18*h* 25*m*. to 18*h*. 27*m*.
		M_E	18 26 45	9	[1]6,000			
		M_N	18 26 30	8		[1]8,500		
		F	18 35 ..					
24		e_E	5 30 40					Seismographs not in operation from Feb. 15, 17*h*. 02*m*. to Feb. 18, 22*h*. 42*m*.
		e_N	5 32 04					
		L_E	5 35 10					
		L_N	5 33 30					
		M_E	5 35 35	8	[1]1,600			
		M_N	5 34 28	22		[1]1,500		
		F_E	5 40 ..					
		F_N	5 58 ..					
ILLINOIS. *U. S. Weather Bureau, Chicago.*								
1922.			*H. m. s.*	*Sec.*	*μ*	*μ*	*Km.*	
Feb. 14		P	12 38 37				2,500	
		S	12 42 40					
		F	13 *postea*					Merged in next quake.
14		e?	13 04 47					
		S?	13 15 45					
		L	13 47 50	40				
		L	13 56 50	35				
		L	14 05 ..	25				
		L	14 18 ..	18				
		F	15					
16		P	3 20 39				3,400	
		iS	3 25 47					
		L	3 28 55					
		M_E	3 33 30		[1]5,000			
		F	5 20 *ca*					

[1] Trace amplitude.

TABLE 2.—*Instrumental seismological reports, February, 1922*—Contd.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
ILLINOIS. *U. S. Weather Bureau, Chicago*—Continued.								
1922.			*H. m. s.*	*Sec.*	*μ*	*μ*	*Km.*	
Feb. 19		P	22 02 25				2,500	
		S	22 06 32					
		L	22 08 20	16				
		F	23 *ca*					
20		eL	8 34 ..	18				
		F	8 55 *ca*					
24		eL	5 45 ..					Possibly not seismic.
		L	5 46 ..	18				
		F	6 20 *ca*					
28		e	21 22 ..					
		L	21 31 ..	16				
		F	22 10 *ca*					
MARYLAND. *U. S. C. & G. S. Magnetic Observatory, Cheltenham.*								
1922.			*H. m. s.*	*Sec.*	*μ*	*μ*	*Km.*	
Feb. 16		P_N	3 21 52	2				
		e_E	3 25 05					
		e_N	3 23 39					
		S_E	3 27 23					
		e_E	3 29 03	22				
		L_E	3 30 17	12				
		L_N	3 41 34					
		M_E	3 31 06	11	50			
		M_N	3 55 08	10		70		
		C_E	3 33 23					
		F_E	3 50 ..					
		F_N	4 05 ..					
MISSOURI. *St. Louis University, St. Louis.*								
1922.			*H. m. s.*	*Sec.*	*μ*	*μ*	*Km.*	
Feb. 14		eL	11 40 18					
		F	11 43 ..					
16		eP_N	3 20 36				3,000	
		eP_E	3 20 36					
		S_N	3 25 18					
		S_E	3 25 24					
		eL	3 33 12					
		M_N	3 35 48	12.		[1]2,000		
		M_E	3 35 ..	15	[1]2,000			
		F	3 47 ..					
NEW YORK. *Cornell University, Ithaca.*								
1922.			*H. m. s.*	*Sec.*	*μ*	*μ*	*Km.*	
Feb. 14		e_N	12 47 ..	7				Disturbances having a period of 20 sec. from 14:03 to 14:09 may be a part of this quake.
		F_N	12 54 ..					
16		S?n	3 26 22	5				Micros obscure preceding part.
		e	3 28 25	11				
		L	3 31 07	21				
		F	4 05 ..					
19		eL	22 06 ..	13				
		L	22 07 50	17				
		F	22 20 ..					
NEW YORK. *Fordham University, New York.*								
1922.			*H. m. s.*	*Sec.*	*μ*	*μ*	*Km.*	
Feb. 16		P_N	3 20 14					Obscured by micros.
		S_N	3 26 16					
		M	3 34 *ca*					
CANAL ZONE. *Panama Canal, Balboa Heights.*								
1922.			*H. m. s.*	*Sec.*	*μ*	*μ*	*Km.*	
Feb. 16		P_E	3 16 24				640ca	Direction probably NW.
		P_N	3 16 28					
		S_E	3 17 36					
		S_N	3 17 40					
		L_E	3 18 16					
		L_N	3 18 24					
		M_E	3 19 44		[1]3,000			
		M_N	3 20 38			[1]9,000		
		F_E	3 43 00					
		F_N	3 45 00					

[1] Trace amplitude.

TABLE 2.—*Instrumental seismological reports, February, 1922*—Contd.

VERMONT. *U. S. Weather Bureau, Northfield.*

1922.			*H. m. s.*	*Sec.*	*μ*	*μ*	*Km.*	
Feb. 16		eL	3 29 ..	18				
		F	4					

PORTO RICO. *U. S. C. & G. S. Magnetic Observatory, Vieques.*

1922.			*H. m. s.*	*Sec.*	*μ*	*μ*	*Km.*	
Feb. 16		P_E	3 19 30					
		P_N	3 19 47	5				
		S_E	3 23 12					
		L_E	3 24 56	17				
		L_N	3 27 30					
		M_E	3 40 45	10	40			
		M_N	3 29 53	10		100		
		F_E	3 50 ..					
		F_N	3 40 ..					

CANADA. *Dominion Observatory, Ottawa.*

1922.			*H. m. s.*	*Sec.*	*μ*	*μ*	*Km.*	
Feb. 16		O	3 14 40				3,720	Press report, received after readings were made, states quake occurred in Nicaragua at 3.14.
		iP_N	3 21 37					
		iS_E	3 27 08					
		eL	3 33 ..					
		L_N	3 38 ..	(10)				
		L_E	3 38 ..	(13)				
		F	4 35 ..					
19		$eS?_E$	22 04 19					
		eL	22 07 30					
		L_E	22 12 ..	15				
		F	22 40 ..					
20		e_N	8 31 48					
		eL	8 37 30					
		F	8 50 ..					
28		e	21 20 08					
		e	21 24 40					
		eL	21 31 42					
		F	22 10 *ca.*					

CANADA. *Dominion Meteorological Service, Toronto.*

1922.			*H. m. s.*	*Sec.*	*μ*	*μ*	*Km.*	
Feb. 14		eL	14 03 36					Distant.
		eL	14 05 12					
		M	14 12 42		[1] 700			
		F						Micros.
16		e?	3 24 12					Possibly Nicaragua.
		S	3 28 00					
		eL	3 32 42					
		eL	3 38 12					
		M	3 40 24		[1] 1,200			
		F						Micros.
19		L	22 14 54					
		M	22 17 06		[1] 200			
		F						Do.
20		eL	8 40 36					
		M	8 44 36		[1] 100			
		F	8 48 00					
28		L	21 30 42					Doubtful as to being seismic.
		M	21 32 30					
		F						Micros.

CANADA. *Dominion Meteorological Service, Victoria.*

1922.			*H. m. s.*	*Sec.*	*μ*	*μ*	*Km.*	
Feb. 2		L	3 39 41					
		M	3 44 06		[1] 100			
		F	3 53 27					
5		L	10 30 46					
		M	10 34 26		[1] 200			
		F	10 40 16					
14		M	14 15 00		[1] 500			Time unreliable; paper slipping.
16		e	3 36 31					Do.
		L	3 42 31					M, [1] 1500.
24		L	5 28 28					No record, 18th-21st; paper not paying out.
		M	5 36 49		[1] 200			
		F	5 48 14					
26		L	9 24 27?					
		M	9 29 02		[1] 100			
		F	9 38 13					

[1] Trace amplitude.

No earthquakes were recorded during February, 1922, at the following stations:

COLORADO. *Regis College*, Denver.

Reports for February, 1922, have not been received from the following stations:

ALABAMA. *Spring Hill College*, Mobile.
ALASKA. *U. S. C. and G. S. Magnetic Observatory*, Sitka.
DISTRICT OF COLUMBIA. *Georgetown University*, Washington.
MASSACHUSETTS. *Harvard University*, Cambridge.
MISSOURI. *St. Louis University*, St. Louis.

TABLE 3.—*Late reports.* (*Instrumental.*)

HAWAII. *U. S. C. & G. S. Magnetic Observatory, Honolulu.*

1921.			*H. m. s.*	*Sec.*	*μ*	*μ*	*Km.*	
Dec. 2		e_N	21 08 ..					Very slight. Nothing on E.
		F_N	21 18 ..					
8		e_E	12 55 40					
		e_N	12 54 38					
		M_E	12 58 00	10	[1] 1,400			
		M_N	12 58 00	12		[1] 2,100		
		F_E	13 04 ..					
		F_N	13 02 ..					
18		P_E	15 41 45	2				Greater part of E record lost. L waves apparent at times on E but can not be determined on N. Actual maximum at 15.51.42, 9.5 mm.
		$PR1_N$	15 45 03					
		S_N	15 51 19	10				
		$SR2_N$	16 00 20	19				
		F_N	16 26 ..					
31		e	0 12 04					
		M_E	0 14 42	6	[1] 2,000			
		M_N	0 14 26	6		[1] 2,600		
		F	0 18 ..					
1922.								
Jan. 1		eP_N	19 54 27	8				L doubtful.
		iS	20 00 59	12				
		L_E	20 04 01	18				
		L_N	20 04 01	12				
		M_E	20 06 25	12	[1] 18,500			
		M_N	20 08 14	18		[1] 13,000		
		e_E	20 08 42	20				
		e_N	20 08 32	20				
		F_E	21 46 ..					
		F_N	21 51 ..					
5		e_E	9 25 44	8				
		e_N	9 25 32					
		F_E	9 31 ..					
		F_N	9 32 ..					
6		S_E	14 34 45					
		S_N	14 35 15					
		e_E	14 41 17					
		L_E	14 52 30	17				
		L_N	14 53 00	28				
		M_E	14 54 44	17	[1] 3,300			
		M_N	15 36 10	13		[1] 3,100		
		F_E	16 27 ..					
		F_N	16 15 ..					
9		e_N	5 52 01					No record on E.
		F_N	6 18 ..					
14		e_E	9 14 05					
		e_N	9 17 05					
		M_E	9 19 30	8	[1] 2,900			
		M_N	9 19 40	8		[1] 3,000		
		F	9 25 ..					
17		P_E	4 02 25	3				Actual M_E occurs at 4.12.35, 25.8 mm.; M_N at 4.13.13 9.5 mm.
		P_N	4 02 35	3				
		S_E	4 11 55	15				
		S_N	4 12 00					
		$SR1_N$	4 17 01					
		eL_E	4 31 55	25				
		M_E	4 32 50	20	[1] 4,000			
		F_E	6 15 ..					
		F_N	5 53 ..					
19		P_E	22 18 18					
		P_N	22 18 08					
		S_E	22 25 28					
		S_N	22 25 32	16				
		L_E	22 31 30	20				
		L_N	22 31 18	20				
		M_E	22 33 00	23	[1] 3,200			
		M_N	22 37 30	17		[1] 2,400		
		F_E	23 15 ..					
		F_N	23 09 ..					
22		iP	3 38 08	11				End portion lost on N.
		S_E	3 41 10	18				
		S_N	3 41 17	11				
		L_E	3 42 08					
		L_N	3 42 14	32				
		M_E	3 44 15	12	[1] 16,000			
		M_N	3 44 20	21		[1] 15,000		
		F_E	5 08 ..					

[1] Trace amplitude.

TABLE 3.—*Late reports*—Continued.

HAWAII. *U. S. C. & G. S. Magnetic Observatory, Honolulu*—Contd.

1922.			H. m. s.	Sec.	μ	μ	Km.	
Jan. 22	....	P_E....	20 58 50	......	......	......	......	
		P_N....	20 58 47	7	......	......	......	
		S_E....	21 01 46	......	......	......	......	
		L_E....	21 02 40	15	......	......	......	
		L_N....	21 02 52	15	......	......	......	
		M_E....	21 04 02	12	[1] 8,000	......	......	
		M_N....	21 04 48	10	......	[1] 7,500	......	
		F_E....	22 17 ..	......	......	......	......	
		F_N....	22 30 ..	......	......	......	......	
26	....	P_E....	9 26 27	2	......	......	......	N not operating; F lost in next quake.
		L_E....	9 34 25	10	......	......	......	
		M_E....	9 35 45	9	[1] 3,500	......	......	
26	....	eL_E...	9 45 20	18	......	......	......	N not operating; P probably lost in previous quake; recorded on Z variometer from 9.46 to 9.49.
		M_E....	9 46 44	8	[1] 16,800	......	......	
		F_E....	11 08 ..	......	......	......	......	

[1] Trace amplitude.

TABLE 3.—*Late reports*—Continued.

HAWAII. *U. S. C. & G. S. Magnetic Observatory, Honolulu*—Contd.

1922.			H. m. s.	Sec.	μ	μ	Km.	
Jan. 31	....	iP.....	13 24 10	3	......	......	......	Spot moving too rapidly to record between SR and C. Greatest amplitude recorded is tabulated. Recorded on D, H, and Z variometers.
		$PR1_E$.	13 25 11	......	......	......	......	
		$PR2_N$.	13 25 20	......	......	......	......	
		S_N....	13 29 38	11	......	......	......	
		e_E.....	13 31 39	11	......	......	......	
		e_N....	13 31 10	......	......	......	......	
		$SR1_N$.	13 31 40	......	......	......	......	
		$SR2_E$.	13 32 10	......	......	......	......	
		M.....	....	......	[1] 85,000	[1] 85,000	......	
		C_E....	13 34 20	11	......	......	......	
		C_N....	13 35 ..	10	......	......	......	
		F_E....	16 45 ..	......	......	......	......	
		F_N....	16 22 ..	......	......	......	......	

[1] Trace amplitude.

Chart I. Hydrographs of Several Principal Rivers, February, 1922.

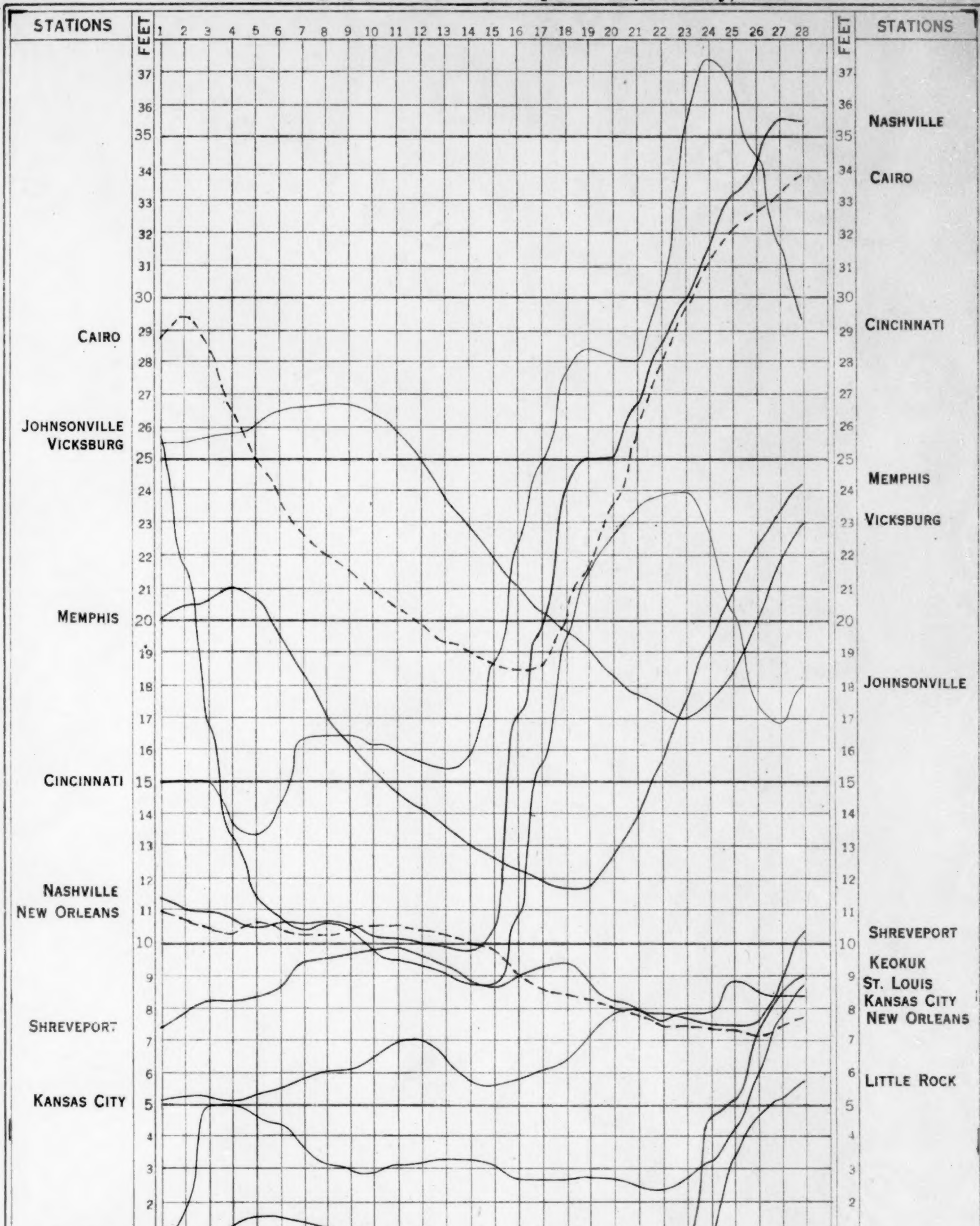


Chart II. Tracks of Centers of Anticyclones, February, 1922. (Inset) Departure of Monthly Mean Pressure from Normal.

(Plotted by Wilfred P. Day.)

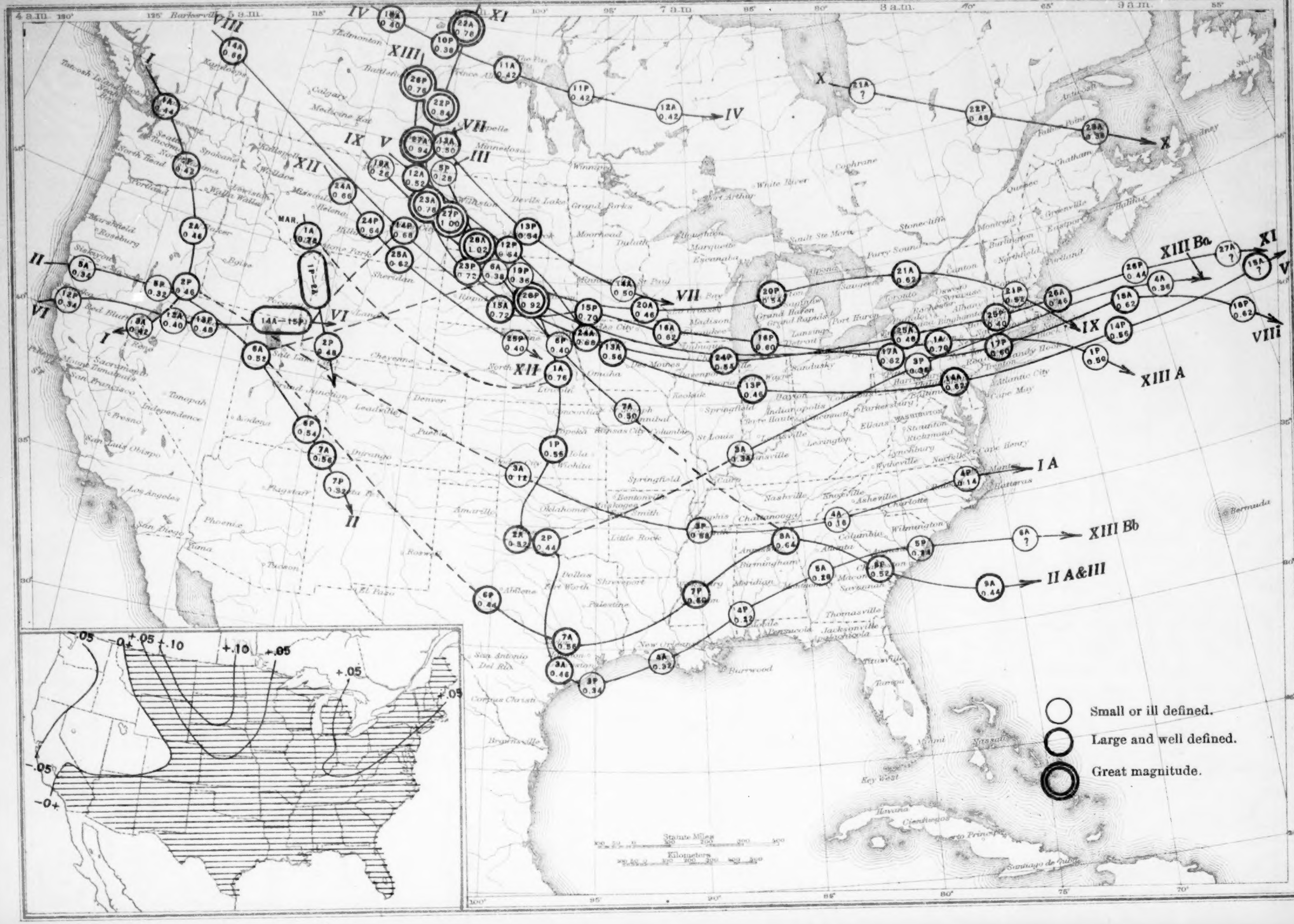


Chart III. Tracks of Centers of Cyclones, February, 1922. (Inset) Change in Mean Pressure from Preceding Month.
(Plotted by Wilfred P. Day.)

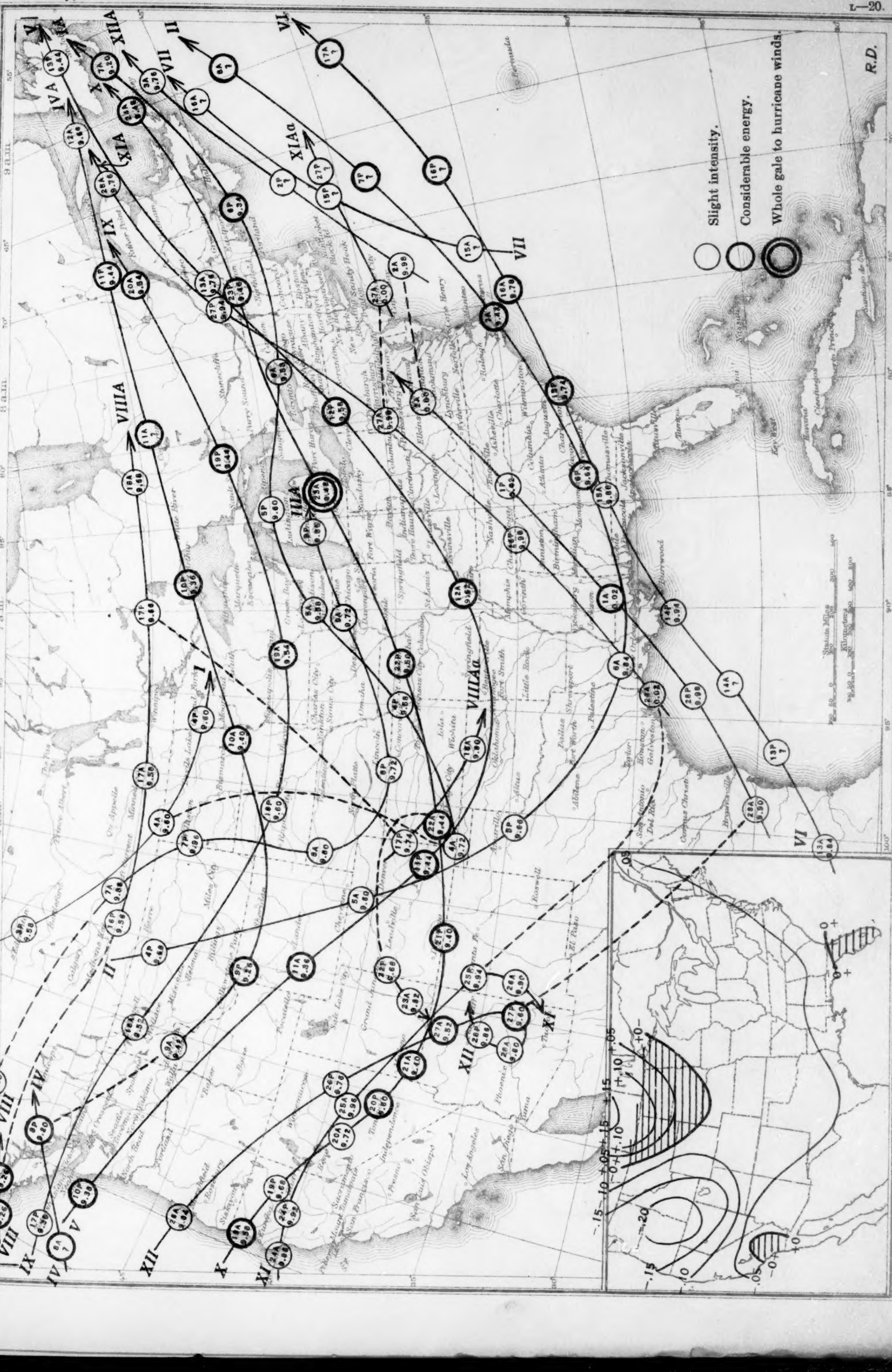
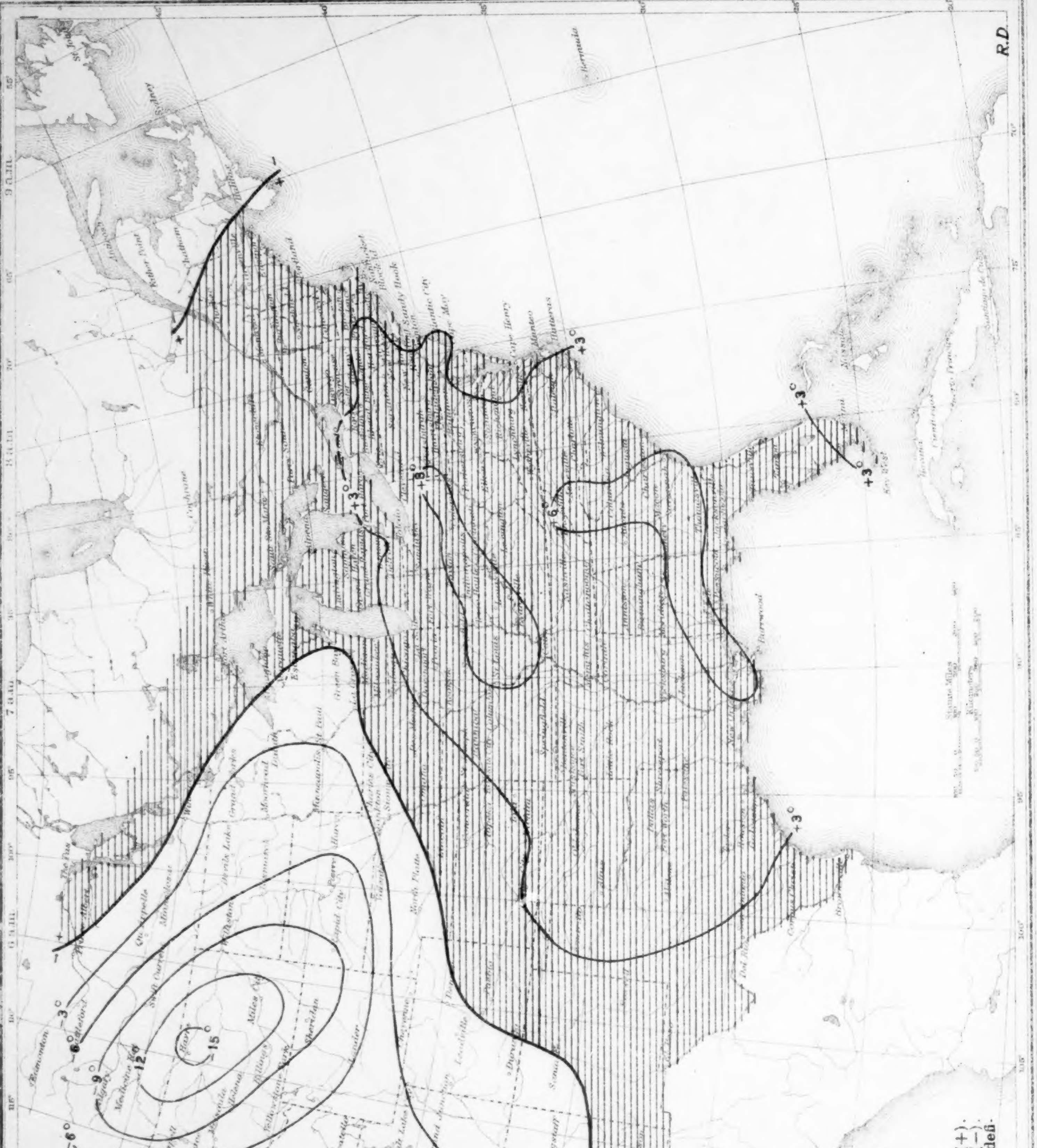


Chart IV. Departure (°F.) of the Mean Temperature from the Normal, February, 1922.



Shaded portions show excess (+).
Unshaded portions show deficiency (−).
Lines show amount of excess or deficiency.

Chart V. Total Precipitation, Inches, February, 1922. (Inset) Departure of Precipitation from Normal.

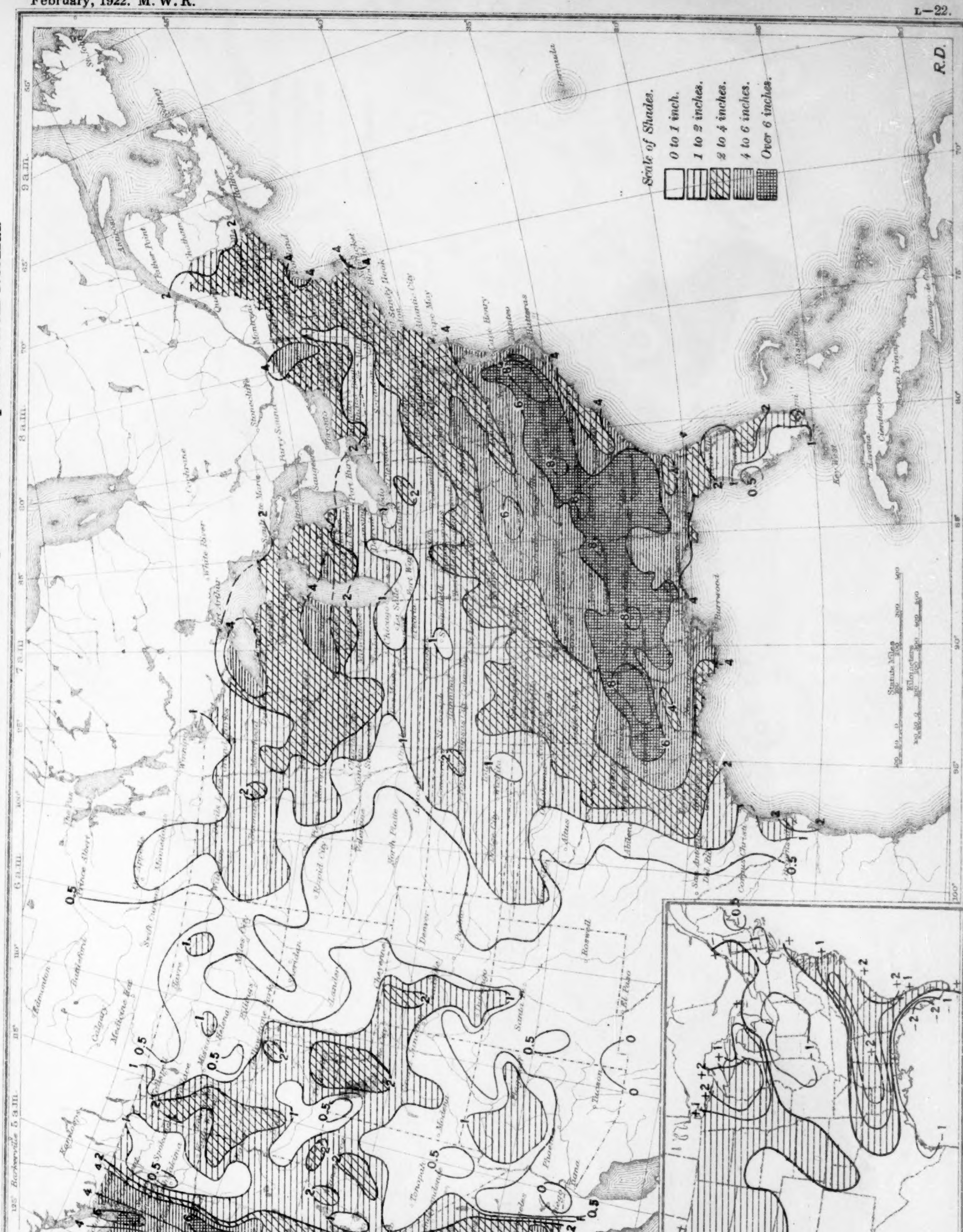


Chart VI. Percentage of Clear Sky between Sunrise and Sunset, February, 1922.

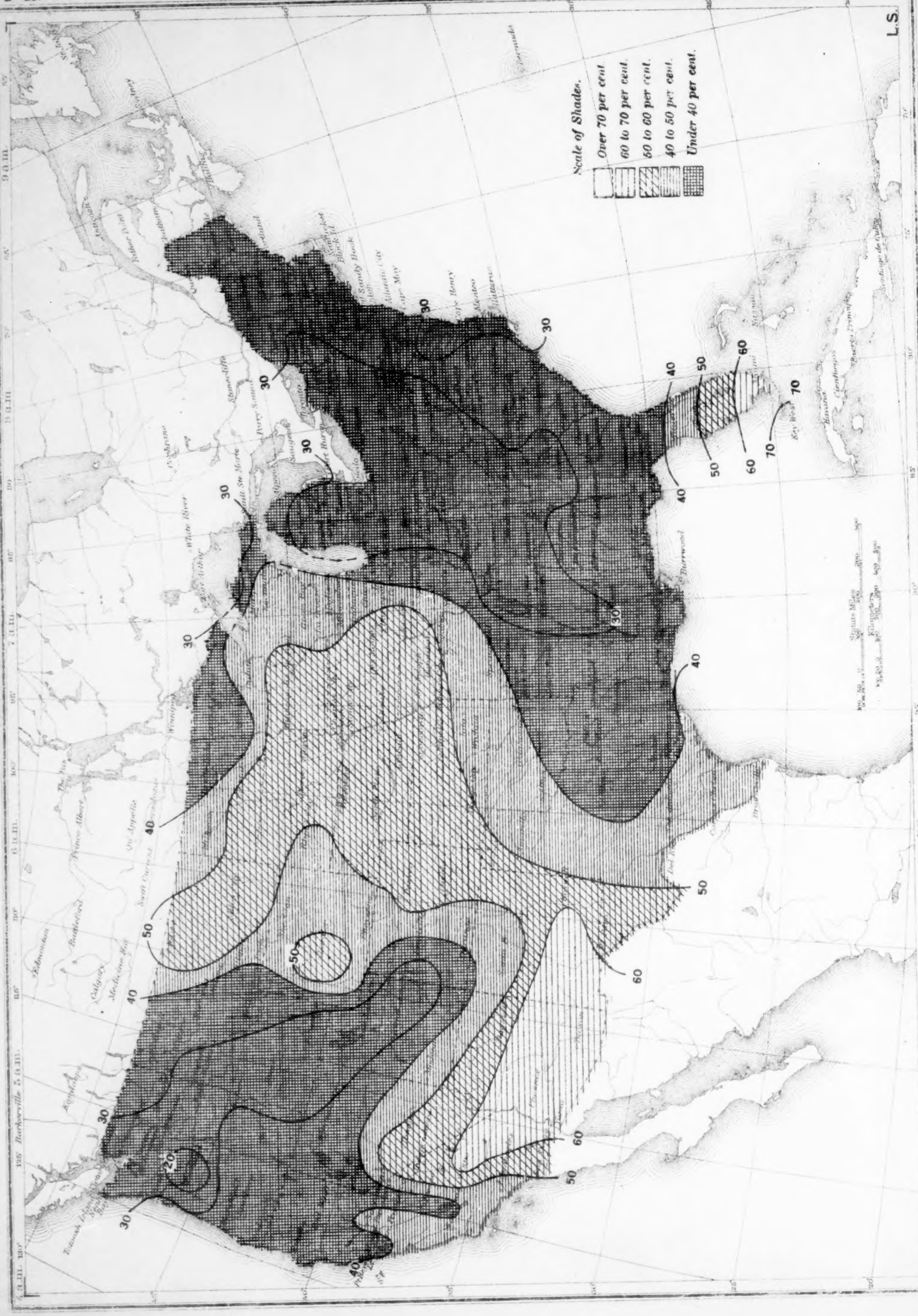


Chart VII. Isobars at Sea-level and Isotherms at Surface; Prevailing Winds, February, 1922.

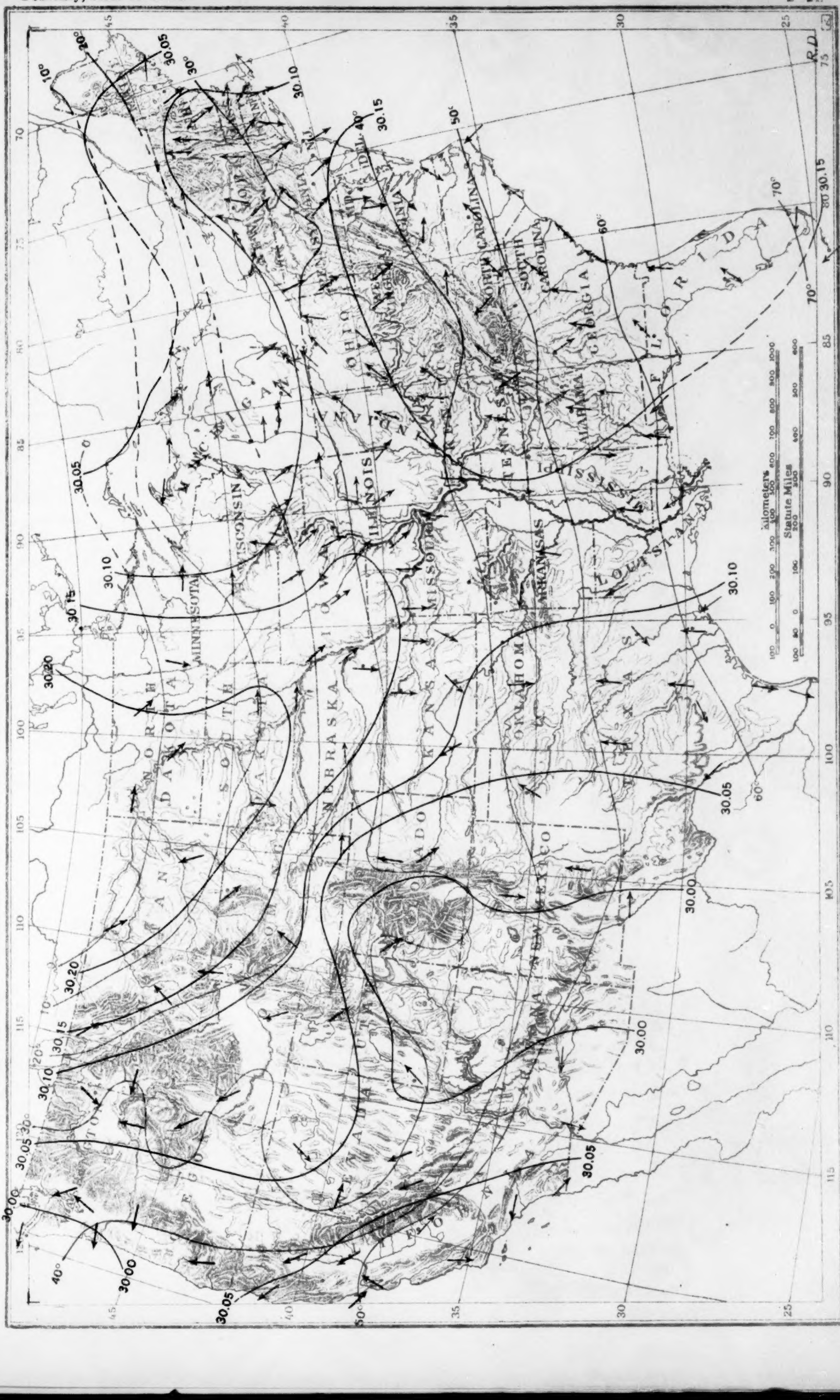


Chart VIII. Total Snowfall, Inches, February, 1922. (Inset) Depth of Snow on Ground at end of Month.

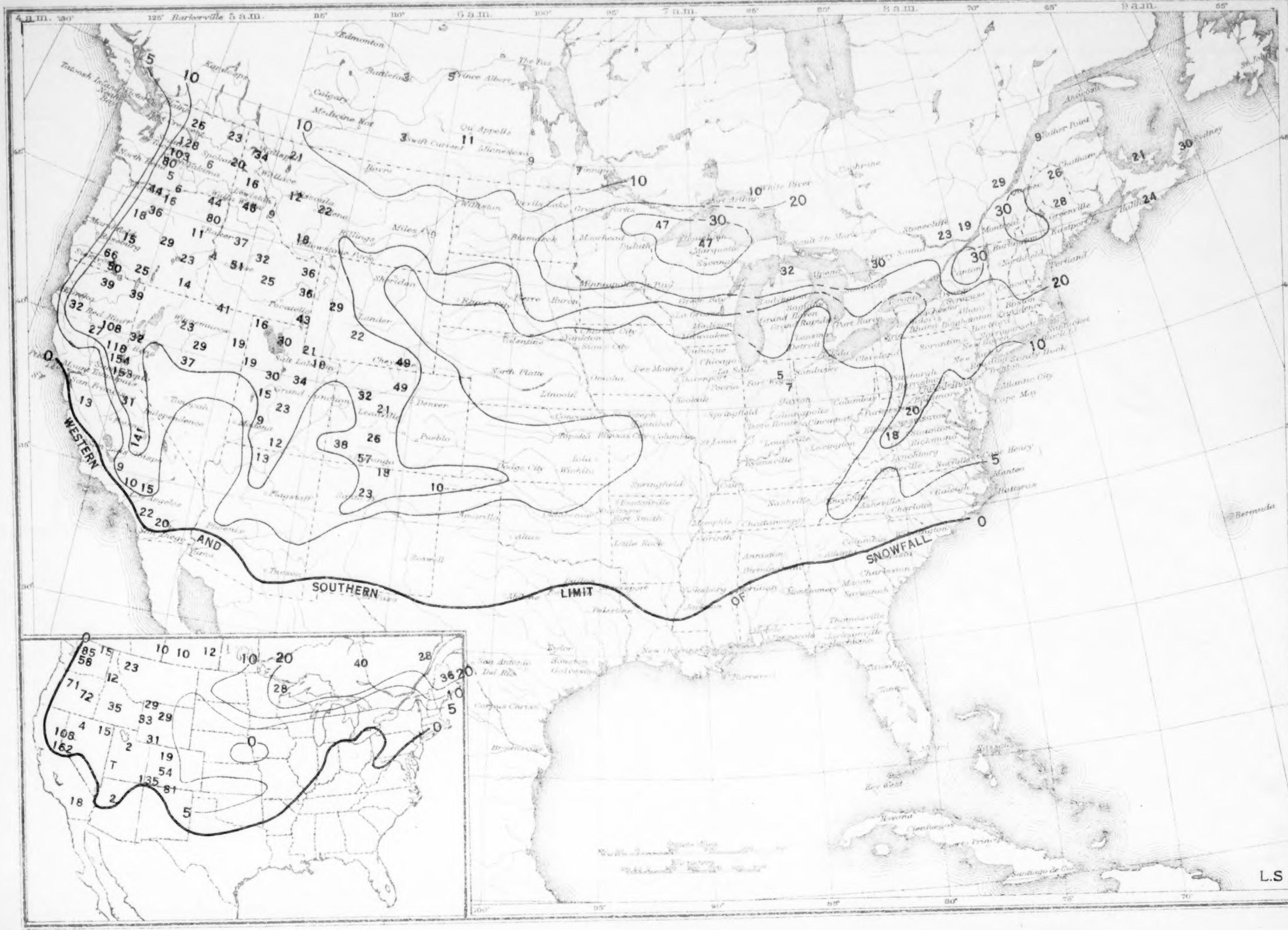


Chart IX. Weather Map of North Atlantic Ocean, February 1, 1922

Chart IX. Weather Map of North Atlantic Ocean, February 1, 1922.

(Plotted by F. A. Young.)

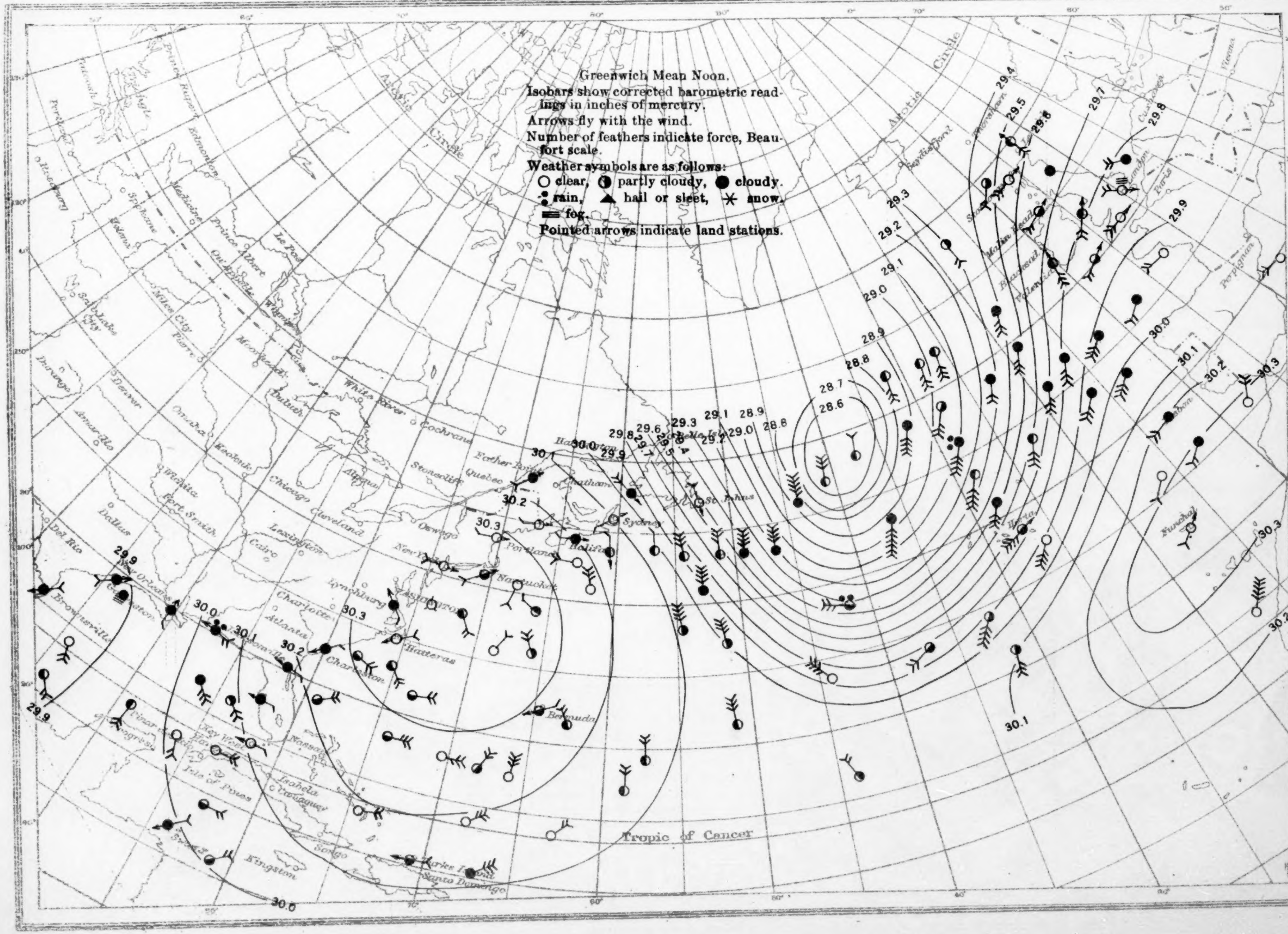


Chart X. Weather Map of North Atlantic Ocean, February 2, 1922.

(Plotted by F. A. Young.)

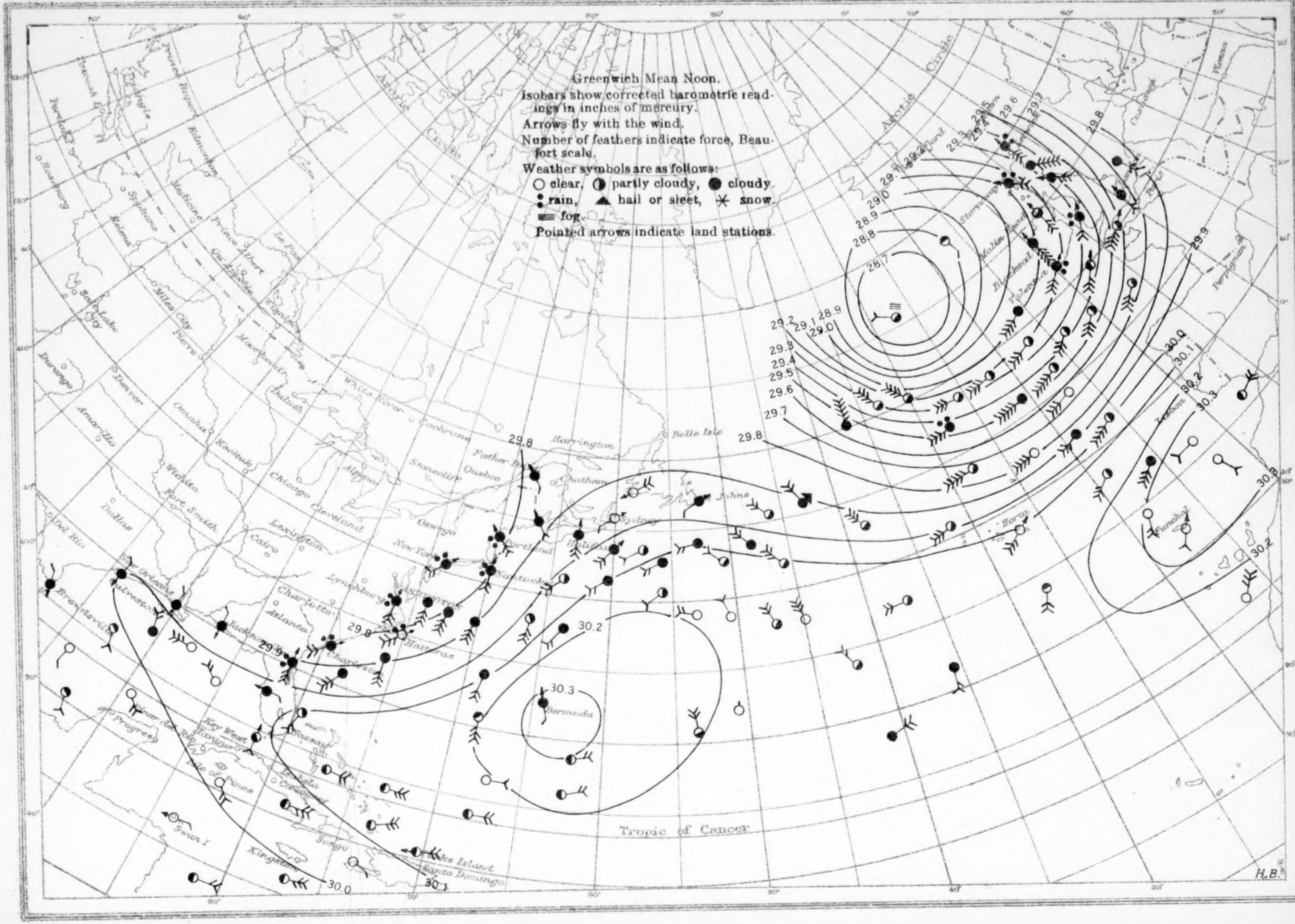


Chart XI. Weather Map of North Atlantic Ocean, February 3, 1922.

(Plotted by F. A. Young.)

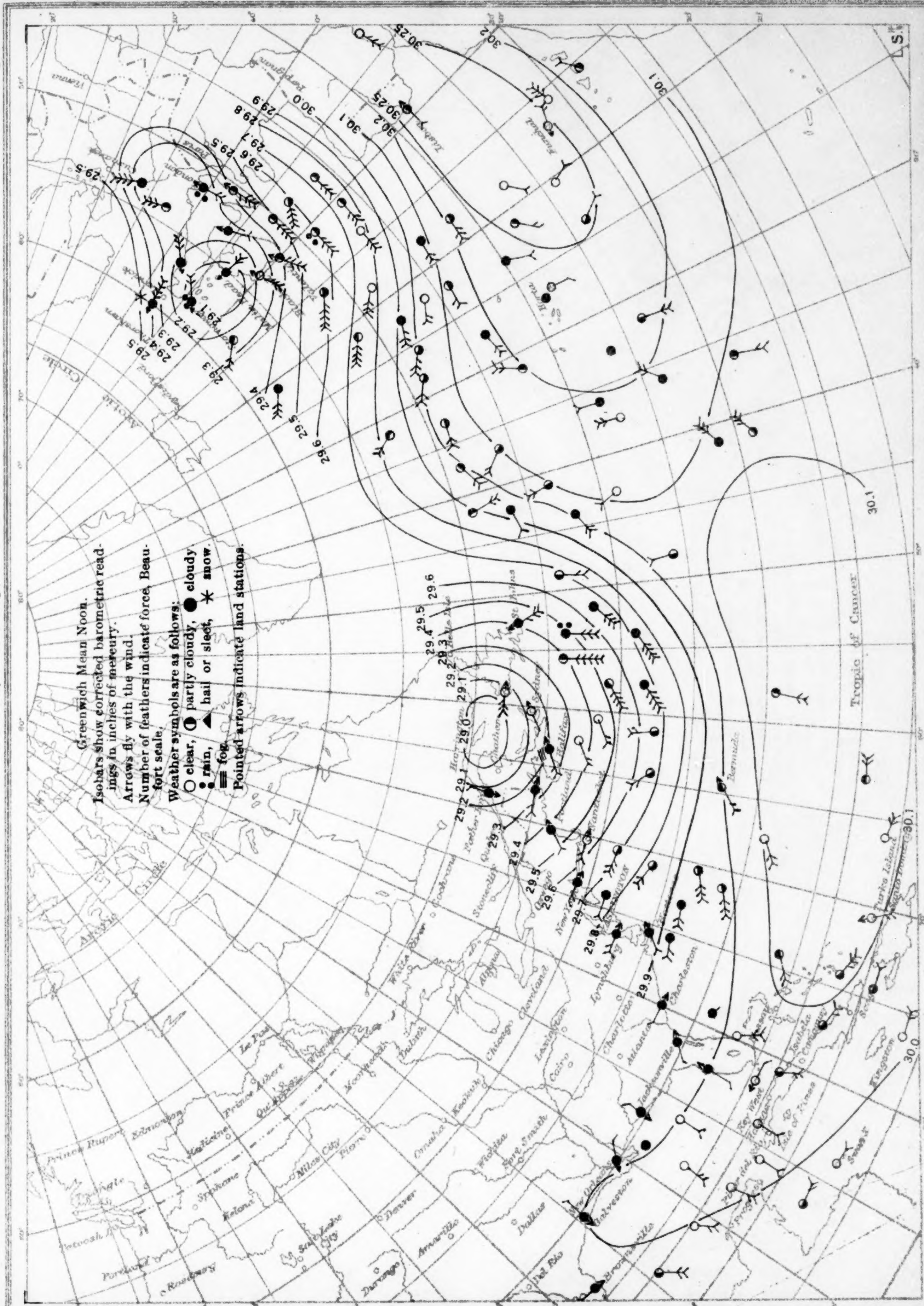


Chart XII. Weather Map of North Atlantic Ocean, February 7, 1922.

(Plotted by F. A. Young.)

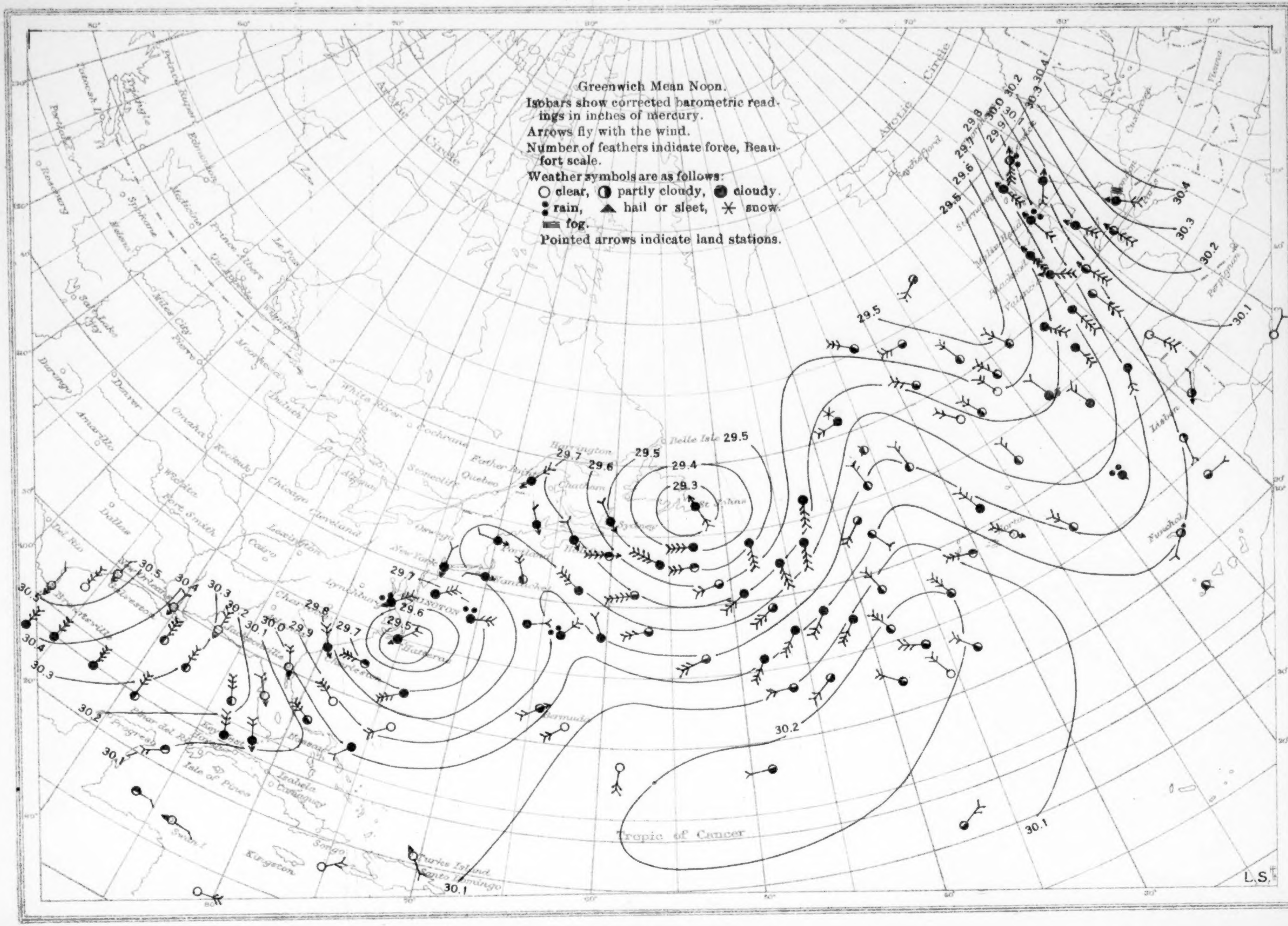


Chart XIII. Weather Map of North Atlantic Ocean, February 8, 1922.

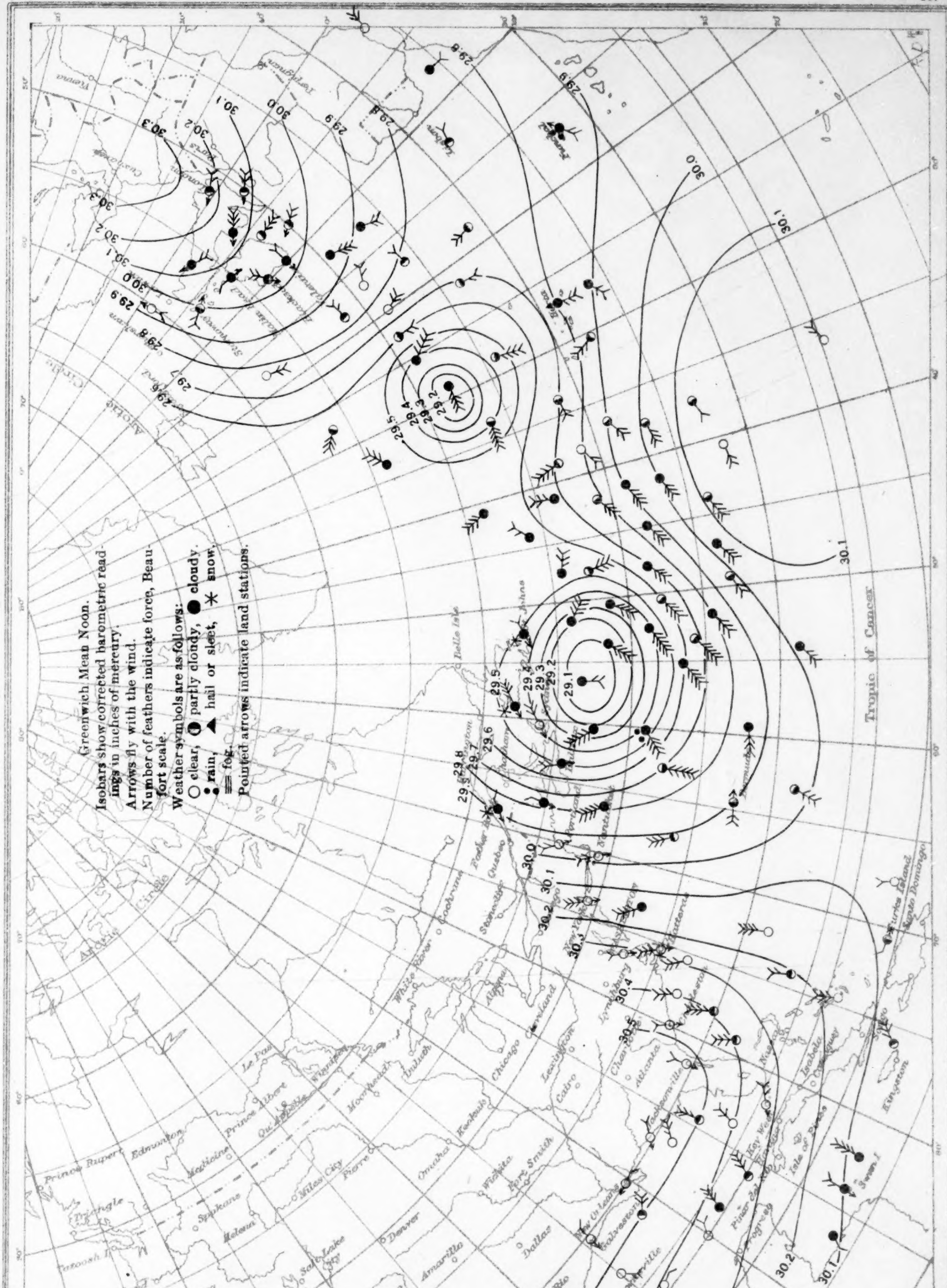


Chart XIII. Weather Map of North Atlantic Ocean, February 8, 1922.
(Plotted by F. A. Young.)

Chart XIV. Weather Map of North Atlantic Ocean, February 9, 1922.

(Plotted by F. A. Young.)

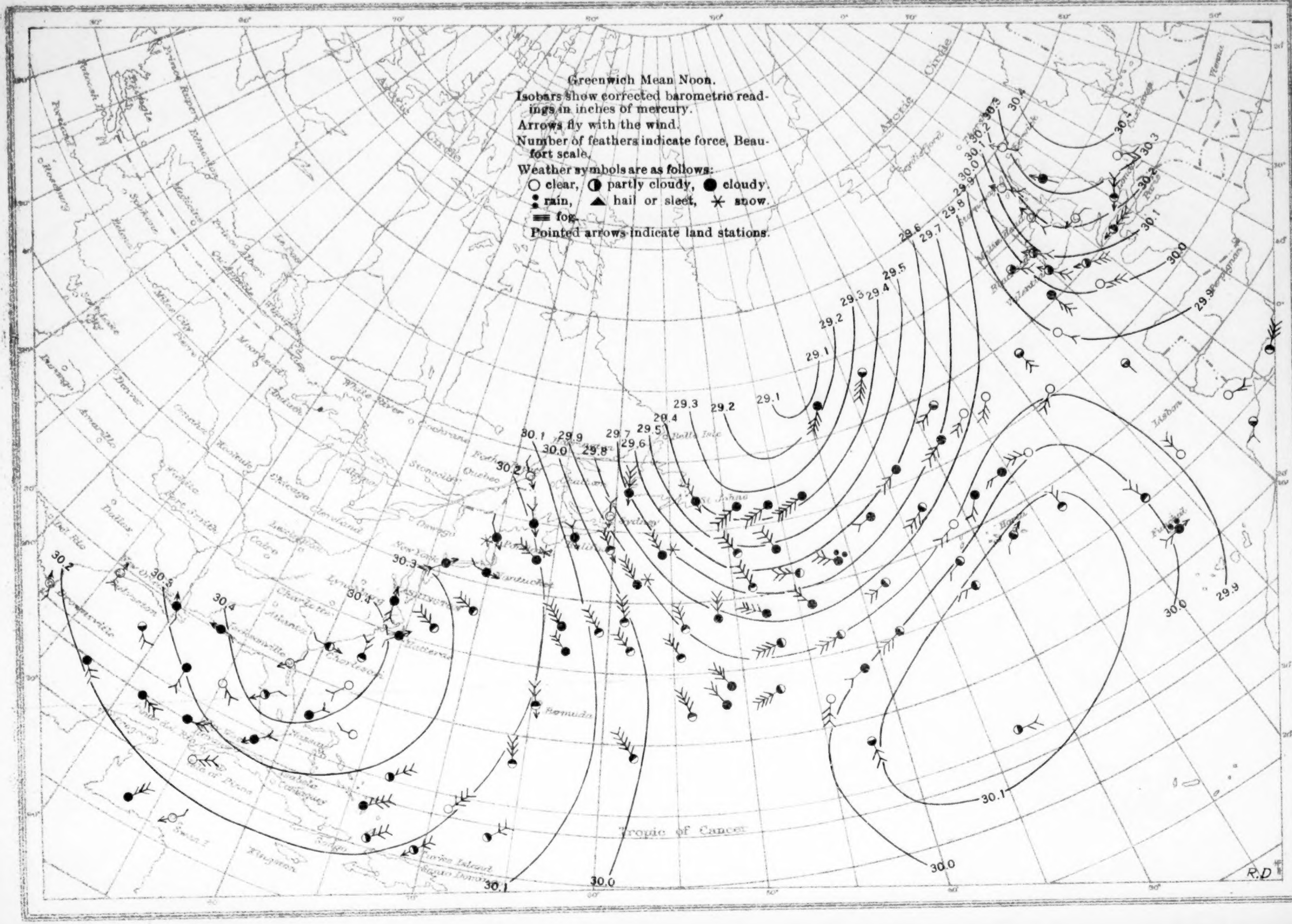


Chart XV. Weather Map of North Atlantic Ocean, February 16, 1922.

Chart XV. Weather Map of North Atlantic Ocean, February 16, 1922.

(Plotted by F. A. Young.)

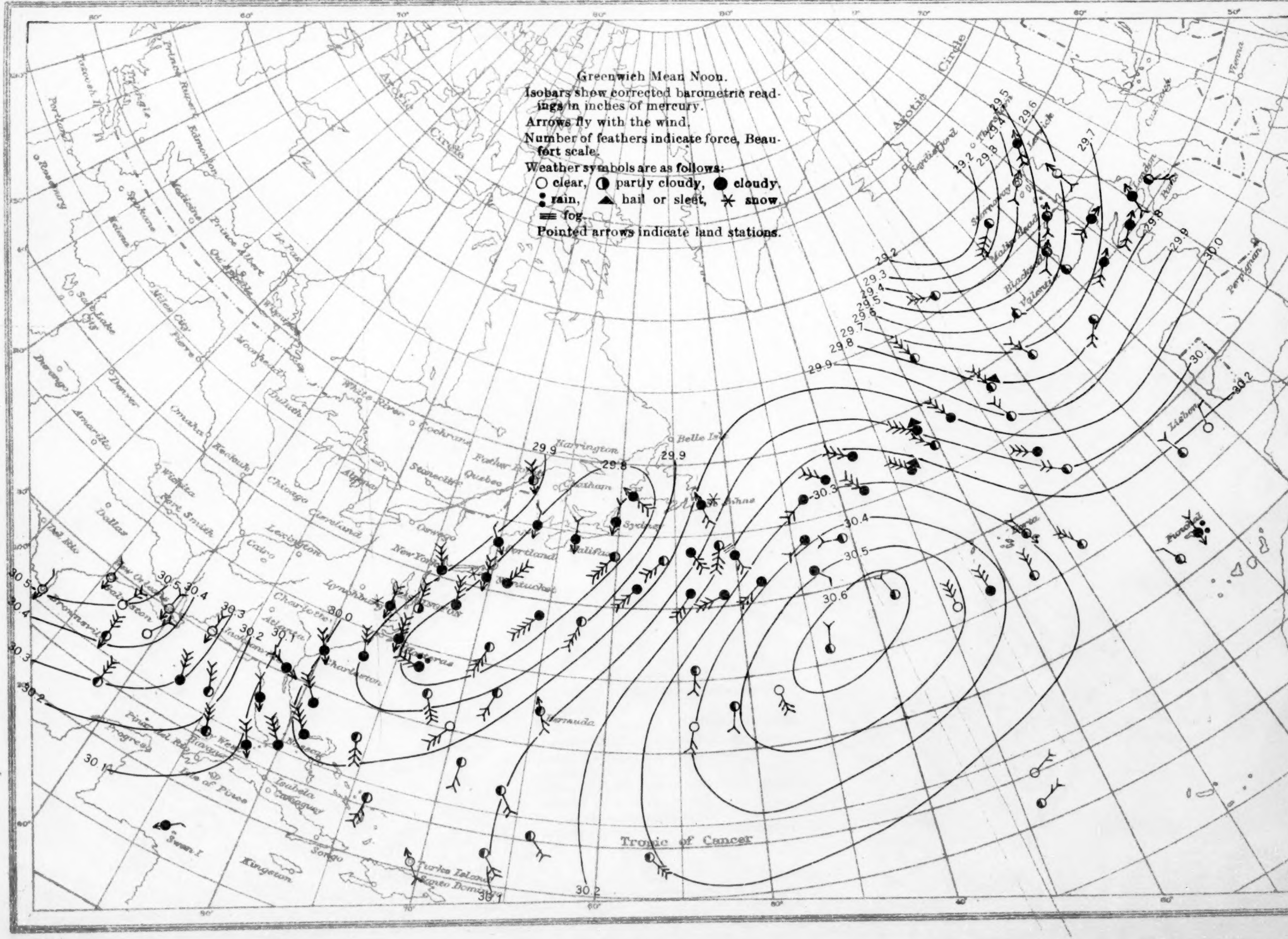
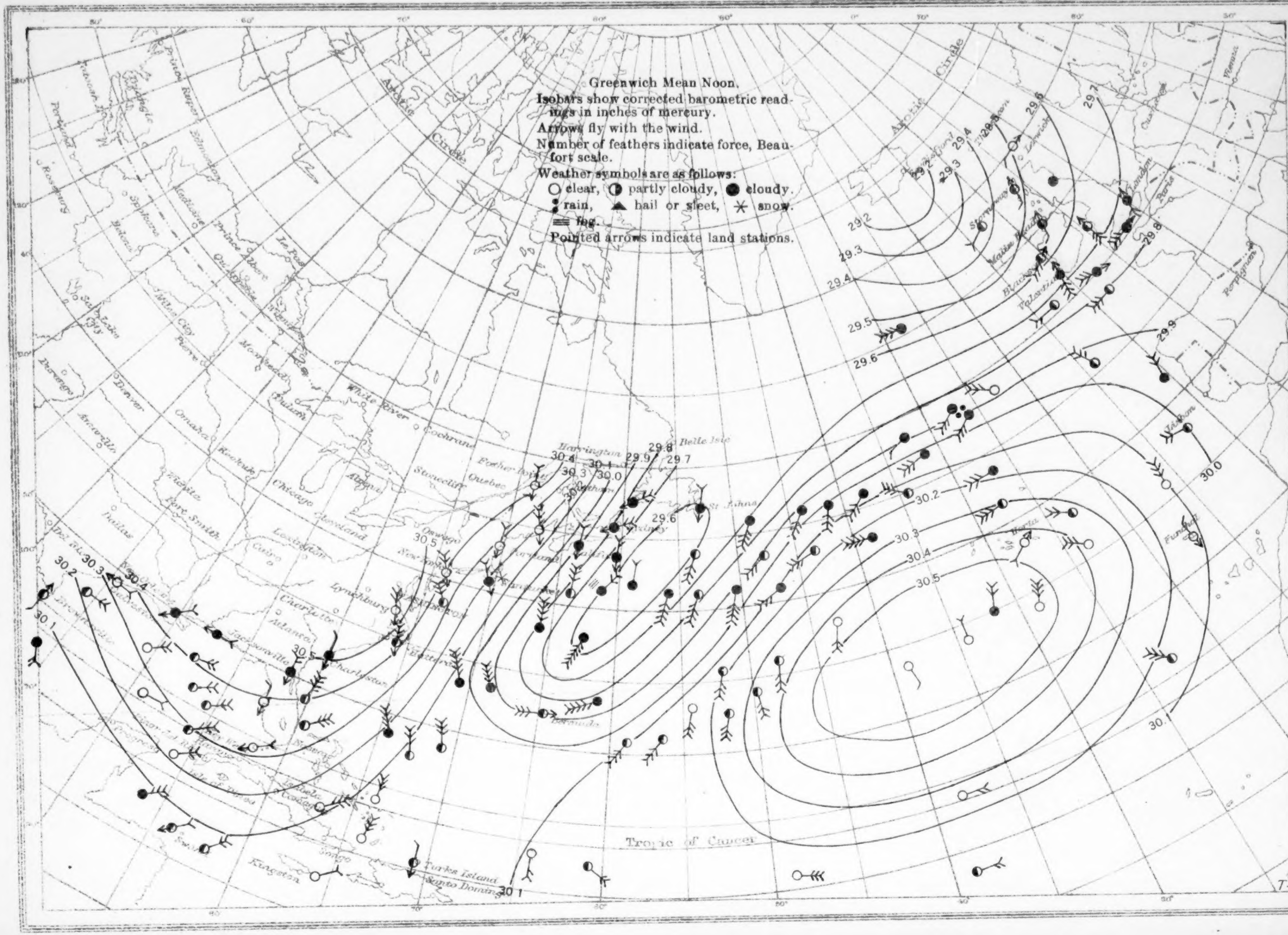


Chart XVI. Weather Map of North Atlantic Ocean, February 17, 1922.

(Plotted by F. A. Young.)



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FEBRUARY, 1922.

CONTENTS.

CONTRIBUTIONS, ABSTRACTS, AND BIBLIOGRAPHY.

WEATHER OF THE MONTH.

† In marine separate.

CORRIGENDA.

Review, October, 1921:

Pages 544, 546, and 547, Tables 1, 3, and 4, respectively, the heading: "Yield (in tons per 100 acres)" *should be:* "Yield (in kilograms per hectare)."
Pages 545, 546, and 547, the left-hand margins of figures 1, 2, 3, and 4 *should read:* "Yield in kilograms per hectare."
In Charts II and III (following page 538), in the headline the terms "SUMMER" and "WINTER" *should be* interchanged.

Review, January, 1922:

Page 10, second column, fourth line from bottom, the word "contract" *should read* "contrast."